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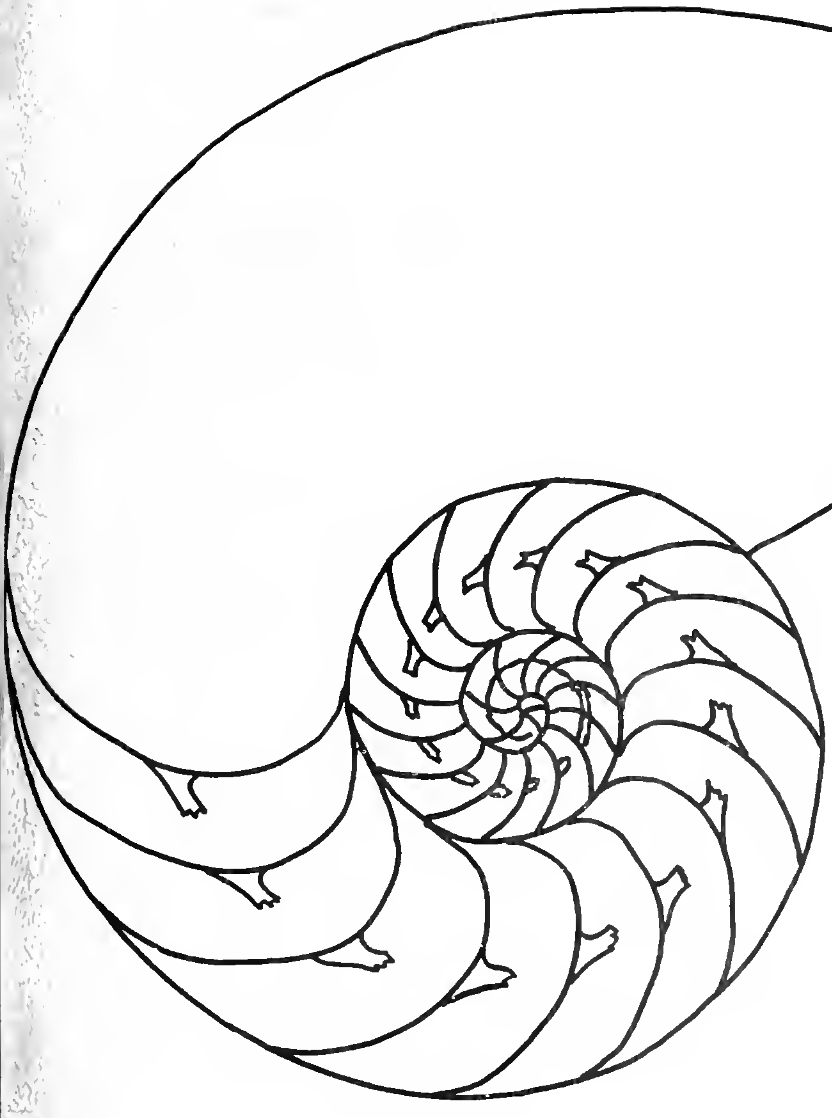

A quarterly devoted to malacology and the interests of conchologists

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CONTENTS

PUBLICATIONS RECEIVED

Mollusca (Section 9), 1983, *The Zoological Record*, vol. 117, 491 pp. Covers the literature for the year 1980. BIOSIS, 2100 Arch St., Philadelphia, PA 19103-1399.

Inaba, Akihiko. 1982. *Molluscan Fauna of the Seto Island Sea, Japan*. 181 pp., 4 pls. Hiroshima Shell Club, Mukaishima Marine Biol. Station, Onomichi P. O., Hiroshima Pref., Japan. About $12.50, postage included. A very useful, annotated, modern checklist of 1074 species of mollusks found in the Inland Sea.

Kozloff, Eugene N. 1983. *Seashore Life of the Northern Pacific Coast:* An Illustrated Guide to Northern California, Oregon, Washington and British Columbia. 378 pp, 700 ills., 299 in color. University of Washington Press, Seattle. Reading for ecologists, but skimpy on mollusks, and omitting author and date from the taxa names. $40.00, hardback; $19.95, paper.

Seaward, Dennis R. (editor) 1982. *Sea Area Atlas of the Marine Molluscs of Britain and Ireland*. 53 pp., 746 distributional maps showing records for live mollusks both before and after 1950. Contains annotated checklist of all species in the area. Nature Conservancy Council, Attingham Park, Shrewsbury, Salop, England SY4 4TW.

Oliveira, de, Maury Pinto, et al. 1981. *Catalogo dos Moluscos da Universidade* Federal de Juiz de Fora (Brasil). 520 pp. Lists, with localities and synonyms, the 903 genera and 2,793 species of mollusks, including 12 holotypes, found in this University collection.

Kuroda, T. and T. Habe, 1981 (with Preface by Iwao Taki). *A Catalogue of Molluscs of Wakayama Prefecture, the Province of Kii*. Part I, Bivalvia, Scaphopoda and Cephalopoda. 301 pp., 13 pls. Seto Marine Biol. Lab., Special Pub. Series, vol. 7, no. 1. Excellent annotated checklist with full synonymies, and useful photos of many species. Separates available for about $18.00 from Yasuo Koyama, 19 Nishidaikucho, Wakayama City, Japan 640.

Correction for Last Issue

(Vol. 97, no. 4, p. 146: R. Shelley article)

Fig. 1: the bottom clam valve is from Halfway Pond, Plymouth Co., MA.

Add to the bibliography: Johnson, Richard I. 1970. The Systematics and Zoogeography of the Unionidae (Mollusca: Bivalvia) of the Southern Atlantic Slope Region. Bull. Mus. Comp. Zool. 140:263–449.

The omissions were not those of the author.

RECENT DEATHS

Mrs. **Betty Jane Allen,** longtime amateur conchologist and shell shop owner in South Padre Island, Texas, died September 10, 1983, at the age of 71, after a long illness. She and her late husband, Larry, contributed much valuable material to various museums. She was a co-founder (1959) and first President of the South Padre Island Shell Club. Also see the *Texas Conchologist*, vol. 20, no. 1, p. 13 (1983).

Joseph P. E. Morrison, former Associate Curator of Mollusks at the U. S. National Museum, died suddenly, December 2, 1983, at age 74, at Key West, FL. A biobibliography of our friend, "Joe", appears in this issue of *The Nautilus*.

Alfred J. Ostheimer, III, Philadelphia businessman, explorer, and amateur malacologist, died September 1, 1983, at the age of 74, at his home in Santa Fe, NM. He was a founder of the Pilsbry Chair of Malacology, and headed numerous expeditions to the South Pacific and West Indies for the Academy of Natural Sciences of Philadelphia in the 1960's. He helped finance the launching of the journal, *Indo-Pacific Mollusca* and was the originator of the Natural Science Foundation (of Philadelphia).

MEETINGS

The **American Malacological Union** will hold its 50th Annual Meeting at Norfolk, Virginia, on July 22-27, 1984. Serious amateurs as well as professionals are invited to attend. For further information write Dr. Robert Robertson, President, Dept. Malacology, Academy of Natural Sciences, Nineteenth and the Parkway, Philadelphia, PA 19103. (215-299-1131).

The **Conchologists of America's** (COA) 12th Annual Convention will be held at the Don CeSar Beach Resort at St. Petersburg Beach, Florida, on June 27 through June 30, 1984. It will be hosted by the St. Petersburg Shell Club and welcomes all shell collectors, whether novice or advanced, as well as shell dealers and scientists from around the country and the world. For further information, please contact: Mr. Donald J. Young, 11975 Third Street East, Treasure Island, Florida 33706.

A BIBLIOGRAPHY AND LIST OF THE TAXA OF MOLLUSCA INTRODUCED BY JOSEPH P. E. MORRISON (DECEMBER 17, 1906 -DECEMBER 2, 1983)

Joseph Rosewater
Department of Invertebrate Zoology
National Museum of Natural History
Washington, D.C. 20560

Dr. Joseph P(aul) E(ldred) Morrison was a recognized expert on freshwater, land and estuarine mollusks, and longtime associate curator at the National Museum of Natural History, Smithsonian Institution.

He was born at South Bend, Indiana, on December 17, 1906; attended Transylvania College (1922-1924); University of Chicago (B.S.-1926); and University of Wisconsin (1927-1931, M.S.-1929, Ph.D.-1931). His professional experience prior to joining the Smithsonian in 1934, included: Zoological Specialist, Illinois State Museum (summers of 1923 and 1927); student assistant in Zoology, Transylvania College (1923-1924); Zoologist, Mt. Desert Island Biological Survey (summers 1927-1928); Zoologist, Wisconsin State Natural History Survey (summers 1929-1930); graduate assistant and instructor, University of Wisconsin (1927-1931); Associate Professor, Crane Junior College, Chicago, Illinois (1931-1933), and Kelley High School (1933-1934). He joined the staff of the Division of Mollusks, [then] United States National Museum, in 1934, as a Scientific Aid, became Assistant Curator in 1942, and Associate Curator in 1946, in which capacity he remained until his retirement due to ill health in 1975, having served for over 40 years.

Dr. Morrison's accomplishments in science were many and varied and included contributions in a number of Natural History disciplines. He served as an officer in several societies: The American Malacological Union (Vice President, 1950; President, 1951; Honorary Life Member, 1978); Washington Academy of Sciences (Editor, 1948-1954); National Capital Shell Club (Charter Member; President, 1962); Biological Society of Washington (Vice President, 1961-1963; acting President, 1963-1964); member: Society of Systematic Zoology; Washington Biologists Field Club; National Rifle Association; National Speleological Association; Sigma Xi; Phi Sigma.

His contributions of specimens to the collections of the National Museum of Natural History, and, through exchanges, to the collections of museums throughout the world, are almost countless. These specimens resulted from field work done before his employment at the Smithsonian, resulting in an enormous personal collection of North American mollusks, and from expeditions to: British Guiana (1925); Gulf of Maine (summers of 1927-1928); Indian shell mounds, Pickwick Landing Basin, Tennessee and Alabama (1937); San Jose Island, Pearl Islands, Panama (1944); Marshall Islands (1946, 1947); Raroia, Tuamotu Islands (1952); New Caledonia (1961); Dominica (1965); Mexico (1966). Through the years of his employment at the Smithsonian he collected locally, on weekends, and during vacation excursions at every available opportunity, resulting in massive suites of specimens numbering in the hundreds of thousands bearing his name as collector.

In connection with his collecting activities he invented and redesigned a number of special

aids to capturing natural history specimens. These include a collapsible funnel fish trap and a folding mussel bar, the latter having been patented. In addition, he modified for special purpose collection activities many different types of dredges and nets, and various types of fire arms and ammunition. He was a consultant to the Smithsonian and the U.S. Fish and Wildlife Service on collecting weapons. During World War II he created an experimental 30 cal. M1 Carbine collecting outfit which was offered to the armed forces as a survival kit for service men. He was the only civilian to contribute to the solution of war survival problems – outside of major weapons companies.

Dr. Morrison has the distinction of being one of the few malacologists of our time whose studies include all three of the major faunal groups of mollusks, land, freshwater and marine. His publication list includes well over 100 titles and his list of taxa numbers 175 names of subspecies, species, genera, and subfamilies of mollusks named by him and collaborators. His area of major expertise, the Unionidae, surprisingly, contains less new taxa than certain other groups. Nevertheless, he contributed significantly to the understanding of their relationships through his work and discussions concerning their nomenclature and higher classification. His knowledge of the Mollusca is highly respected at home and abroad, and there are few serious students of Malacology over the last 50 years who have not acknowledged the aid of Dr. J. P. E. Morrison in their work. Dr. Morrison died of a heart attack in Key West, Florida, December 2, 1983, a few days before his 77th birthday. He is survived by his wife, Dorothy Louise (Dunn) Morrison, Apt. 703, 3312 North Side Drive, Key West, FL 33040; and three children.

There follows a list of the molluscan taxa introduced by J. P. E. Morrison, both alone and with others. In the latter category the most significant work was that on the Cyclophorid mollusks written jointly with Paul Bartsch (1942b). Following the taxa list is Dr. Morrison's bibliography arranged chronologically. The dates of publication of papers are annotated a, b, c, etc., where there are more than one per year. These annotated dates are used in the taxa list so that there is no confusion about which publication is cited. The following abbreviations are used in the list of taxa:

AMUB – American Malacological Union Bulletin and/or Annual Reports

ANSP – Academy of Natural Sciences of Philadelphia

BAEB – Bureau of American Ethnology Bulletin

JWAS – Journal of the Washington Academy of Sciences

N – The Nautilus

PBSW – Proceedings of the Biological Society of Washington

SMC – Smithsonian Miscellaneous Collections

USNM – National Museum of Natural History, formerly United States National Museum

USNMB – United States National Museum Bulletin

Taxa of Mollusca Introduced By Joseph P. E. Morrison

adamsi Morrison *Mytilopsis* 1946, SMC 106(6)(3850):46, pl. 1, figs. 4, 7 (attached by byssus to underside of rocks, upper end of lagoon, mouth of Musselshell Creek, SE San Jose Island, Pearl Islands, Panama; Holotype USNM 542183).

agassizi Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:254, pl. 37, figs. 4-6 (Brazil, probably in Amazon River region [sic]; Holotype USNM 57285).

allantayum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:230, pl. 32, figs. 4-6 (Peru; Holotype USNM 524046).

alleei Morrison *Aroapyrgus* 1946, SMC 106(6)(3850):14, pl. 2, fig. 4; pl. 3, fig. 3 (from dead leaves, sticks, etc., in a pool, Allee Stream, Barro Colorado Island, Gatun Lake, Canal Zone, Panama; Holotype USNM 542142).

amazonense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:243, pl. 35, figs. 4-6 (Amazon River, Brazil; Holotype USNM 356102).

Athearnia Morrison 1971b, N 84(3):110; type species by original designation *Anculosa anthonyi* Redfield, 1854.

atratensis Bartsch and Morrison *Calacyclotus* 1942b, USNMB 181:179, pl. 23, figs. 10-12 (mountains near mouth of Atrato River, Colombia; Holotype USNM 206291).

aureum Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:209, pl. 28, figs. 13-15 (Panistlahuaca, Oaxaca, Mexico; Holotype USNM 523970).

australis Morrison *Cochliopina* 1946, SMC 106(6)(3850):23, pl. 2, fig. 13; pl. 3, fig. 14 (lowermost reaches of Musselshell Creek, just above lagoon, SE end [San Jose Island, Pearl Islands, Panama]; Holotype USNM 542165).

avus Bartsch and Morrison *Cyrtotoma* 1942b, USNMB 181:169, pl. 22, figs. 22-24 (Motzorongo, Vera Cruz, Mexico; Holotype USNM 128285).

bakeri Bartsch and Morrison *Adelopoma* 1942b, USNMB 181:149, pl. 40, fig. 5 (Quebrada, Venezuela; Holotype ANSP 140916).

balsasense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:265, pl. 39, figs. 1-3 (Balsas, Peru; Holotype USNM 524126).

Barbacyclus Bartsch and Morrison 1942b, USNMB 181:175; type species by original designation *Cyclophorus underwoodi* DaCosta, 1900.

barretti Morrison *Odostomia* 1965a, PBSW 78:220, fig. 4 (NE Heron Bay, Mississippi; Holotype USNM 635630); not *Odostomia barreti* L. Morlet, 1885, *is Hydrobia* [sic] *boonae* Morrison, 1973.

biangulata Morrison *Quadrula* 1942a, BAEB 129:348, 349, 350, 351, 352, 356 (Tuscumbia, Alabama; Holotype USNM 84221).

bicincta Bartsch and Morrison *Buckleyia* 1942b, USNMB 181:152, pl. 19, figs. 13-15 (Ecuador; Holotype USNM 316063).

boliviense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:260, pl. 38, figs. 7-9 ("Bolivia"; Holotype USNM 307426).

booneae Morrison *Hydrobia* 1973a, N 87(1):28; new name for *Odostomia* [sic] *barretti* Morrison, 1965, not *O. barreti* L. Morlet, 1885.

bowdenensis Morrison *Poteria* 1955d, JWAS 45(5):155 (Miocene fossil beds, Bowden, Jamaica; Holotype USNM 82532a).

brujense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:241, pl. 34, figs. 13-15 (500 feet, Cerro Bruja, Panama; Holotype USNM 251418).

burringtoni Bartsch and Morrison *Aperostoma (Austrocyclotus)* 1942b, USNMB 181:202, pl. 28, figs. 16-18 (Cariaquita, Venezuela; Holotype ANSP 104625).

Calacyclotus Bartsch and Morrison 1942b, USNMB 181:178; type species by original designation *Amphicyclotus olssoni* Pilsbry, 1926.

carabobense Bartsch and Morrison *Aperostoma (Austrocyclotus)* 1942b, USNMB 181:201, pl. 28, figs. 4-6 (Guaremales, Venezuela; Holotype USNM 339947).

carmioli Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:233, pl. 32, figs. 19-21 (Costa Rica; Holotype USNM 25034).

castaneum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:252, pl. 36, figs. 7-9 (Venezuela; Holotype USNM 524087).

chagresensis Morrison *Aroapyrgus* 1946, SMC 106(6)(3850): 14, pl. 2, fig. 3; pl. 3, fig. 4 (small beds of *Chara* and other plants in shallow water near SE side Rio Chagres, near Gatuncilla, Panama; Holotype USNM 542144).

chagresensis Morrison *Lyrodes* 1946, SMC 106(6)(3850):16, pl. 2, fig. 6; pl. 3, fig. 6 (from *Chara* beds, etc., shallow water, near margin of Chagres River, near Gatuncilla, Panama; Holotype USNM 542149).

chesapeakea Morrison *Sayella* 1939b, N 53(2):44 (Broome's Island, Maryland; Holotype USNM 530766).

chocolatum Morrison *Incidostoma* 1955d, JWAS 45(5):158, figs. 10-12 (Papallagta, Ecuador; Holotype USNM 543527).

chrysacme Bartsch and Morrison *Aperostoma (Neocyclotus)* 1942b, USNMB 181:219, pl. 29, figs. 13-15 (Wani, Nicaragua; Holotype USNM 186112).

clarendonensis Morrison *Poteria* 1955d, JWAS 45(5):155; new name for *Ptycocochlis taylori* Bartsch, 1942, not *P. (Cyclobakeria) welchi taylori* Bartsch, 1942.

clarki Morrison *Detracia* 1951a, JWAS 41(1):18, figs. 2, 6 (Key West, Florida; Holotype USNM 594588).

Cochliopina Morrison 1946, SMC 106(6)(3850):18; type species by original designation *Cochliopa riograndensis* Pilsbry and Ferriss, 1906.

colabrensis Morrison *Subcochliopa* 1946, SMC 106(6)(3850): 26; pl. 2, fig. 14; pl. 3, fig. 16 (Rio Colabre, Bayano River drainage, Panama; Holotype USNM 542169).

coloradoense Morrison *Fluminicola* 1940b, N 53(4):125 (Green River, Wyoming; Holotype USNM 526631).

columna Morrison *Retinella (Glyphalinia?)* 1937, PBSW 50:57, pl. 4, figs. 8-10 (Olga, Washington; Holotype USNM 362009).

constrictus Bartsch and Morrison *Tomocyclus* 1942b, USNMB 181:145, pl. 19, fig. 2 (Coban, N Guatemala; Holotype USNM 162315).

cookei Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:215, pl. 29, figs. 10-12 (Uaxactun, Peten Province, Guatemala; Holotype USNM 524006).

costaricense Bartsch and Morrison *Adelopoma* 1942b, USNMB 181:150, pl. 40, fig. 4 (1550 M, Santa Maria, Costa Rica; Holotype USNM 516034).

cumingi Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:224, pl. 31, figs. 19-21 (Colombia; Holotype USNM 307416).

currani Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:261, pl. 38, figs. 1-3 (Rio Gregugy, Bahia, Brazil; Holotype USNM 322360).

Cyclochittya Morrison 1955d, JWAS 45(5):154; type species by original designation *Cyclotus dentistigmatus* Chitty, 1857.

Cyclopomops Bartsch and Morrison 1942b, USNMB 181: 219; new name for *Cyclopoma* Troschel, 1847, not Agassiz, 1833; type species by original designation *Cyclostoma moricandi* Pfeiffer, 1852.

cylindrica Morrison *Panamicorbula* 1946, SMC 106(6) (3850):47, pl. 1, figs. 15, 17 (in drift of Rio Marina mangrove swamp [San Jose Island, Perlas Islands, Panama]; Holotype USNM 542186).

daltei Morrison *Poteria* 1955d, JWAS 45(5):155; new name for *Ptychocochlis welchi* Bartsch, 1942, not *Poteria (Cyclobakeria) welchi* Bartsch, 1942.

diazensis Morrison *Cochliopa* 1946, SMC 106(6)(3850):27, pl. 2, fig. 15; pl. 3, fig. 18 (from leaves, roots, etc., E bank Rio Juan Diaz, just below Las Sabanas Road bridge, E of Panama City, Panama; Holotype USNM 542170).

diminutum Morrison *Incidostoma* 1955d, JWAS 45(5):159, figs. 7-9 (Papallagta, Ecuador; Holotype USNM 543530).

dorotheae Morrison *Donax* 1971a, PBSW 83(48):554, pl. 1, fig. Do (Alligator Point, Franklin County, Florida; Holotype USNM 679773).

dugesiana Morrison *Durangonella* 1945c, N 59(1):21, pl. 3, fig. 3 (near Andocutira, Michoacan, Mexico; Holotype USNM 433473).

dunoonense Bartsch and Morrison *Aperostoma (Cyclohidalgoa) translucidum* 1942b, USNMB 181:273, pl. 30, figs. 7-9 (British Guiana; Holotype ANSP 140876).

Durangonella Morrison 1945c, N 59(1):18; type species by

original designation *Durangonella seemani* (Frauenfeld) = *Hydrobia seemani* Frauenfeld.

dyeri Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:205, pl. 28, figs. 31-33 (La Ceiba, Honduras; Holotype USNM 215592).

ecuadorense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:248, pl. 36, figs. 4-6 (Quito, Ecuador; Holotype USNM 316105).

eldredi Morrison *Conus (Gastridium)* 1955a, JWAS 45(1): 32; new name for *Conus geographus rosea* Sowerby, 1833, not *C. roseus* Fischer, 1807, nor Lamarck 1810; for *C. intermedius* Reeve, 1843, not *C. intermedius* Lamarck, 1810; and for *C. mappa* Crosse, 1858, not *C. mappa* Solander, 1786.

exiguum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:234, pl. 32, figs. 10-12 (Zhorquin Valley, Talamanca, Costa Rica; Holotype USNM 190281).

extremis Morrison *Cochliopina* 1946, SMC 106(6)(3850):22, pl. 2, fig. 11; pl. 3, fig 13 (from small stream with 100- yard lagoon just E of S tip of San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542163).

Fijidoma Morrison, 1952a, AMUB:8; type species by monotypy *Fijidoma laddi* Morrison, 1952.

Filocyclus Bartsch and Morrison 1942b, USNMB 181:157; type species by original designation *Cyclophorus delphinulus* Mousson, 1869.

fischeri Bartsch and Morrison *Cyrtotoma* 1942b, USNMB 181:171, pl. 22, figs. 13-15 (Hacienda Cuatotolapam, Veracruz, Mexico; Holotype USNM 515789).

floridana Morrison *Retinella (Glyphaloides?)* 1937, PBSW 50:56, pl. 4, figs. 11-13 (Pleistocene? near Ocala, Marion County, Florida; Holotype USNM 421084).

flucki Morrison *Diplodon* 1943c, N 57(1):14, pl. 5, figs. 5-9 (Orinoco River above Munduapo, Venezuela; Holotype USNM 521998).

fraternula Morrison *Cochliopina* 1946, SMC 106(6)(3850): 21, pl. 2, fig. 9; pl. 3, fig. 11 (in reaches just above tidewater of Rio Mata Puerco, San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542157).

fultoni Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:242, pl. 35, figs. 1-4[3] ("Brazil"; Holotype USNM 307425).

gemmula Morrison *Donax* 1971a, PBSW 83(48):565, pl. 2, fig. G (Praia do Cassino, Rio Grande, Rio Grande do Sul, Brazil; Holotype ANSP 244125).

globula Morrison *Obovaria subrotundata* 1942a, BAEB 129:348, 349, 350, 351, 352, 360 (Tuscumbia, Alabama; Holotype USNM 85789).

goldmani Bartsch and Morrison *Cyrtotoma* 1942b, USNMB 181:174, pl. 22, figs. 7-9 (Mutaltoyuca, Puebla, Mexico; Holotype USNM 523516).

graminea Morrison *Detracia* 1946, SMC 106(6)(3850):35, pl. 1, fig. 18 (in and under drift, mangrove swamp side of sand barrier, near mouth of Rio Marina, Isla San Jose, Archipielago de las Perlas, Panama; Holotype USNM 542177).

Guianadesma Morrison 1943d, N 57(2):49; type species by original designation *Guianadesma sinuosum* Morrison, 1943.

haughti Bartsch and Morrison *Aperostoma (Cyclohidalgoa) belli* 1942b, USNMB 181:269, pl. 30, figs. 24-26 (south part Department of Santander, Colombia; Holotype USNM 524136).

haughti Morrison *Buckleyia* 1955d, JWAS 45(5):150, figs. 26-28 (stream N of Rio Nuqui, Dept. Choco, Colombia; Holotype USNM 488865).

hedui Bartsch and Morrison *Aperostoma (Ñcidostoma)* 1942b, USNMB 181:191, pl. 26, figs. 1-3; new name for *Cyclotus incomptus* Reeve, 1863, not *Cyclostoma incomptum* Sowerby, 1850 (Brazil; Holotype USNM 307480) [sic].

hinkleyi Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:206, pl. 28, figs. 19-21 (Guatemala; Holotype USNM 523968).

hitomi Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:194, pl. 27, figs. 26-28 (Quito, Ecuador; Holotype USNM 316105).

ignotum Bartsch and Morrison *Cyrtotoma* 1942b, USNMB 181:171, pl. 22, figs. 16-18 (Mexico; Holotype USNM 523515).

Incerticyclus Morrison 1955d, JWAS 45(5):156; type species by original designation *Neocyclotus (Ptychocochlis) bakeri* Simpson, 1895.

Incidostoma Bartsch and Morrison 1942b, USNMB 181:187; type species by original designation *Aperostoma (Incidostoma) malleatum* Bartsch and Morrison, 1942.

insula Morrison *Cyrenoida* 1946, SMC 106(6)(3850):45, pl. 1, figs. 8-11 (from pools in mud of small mangrove swamp, W side San Jose Island, Perlas Islands, Panama; Holotype USNM 542182).

intermedius Morrison *Helicodiscus (Hebetodiscus)* 1942a, BAEB 129:374, 375, 376, 378, 379 (10-11 foot sample, at mound site Lu° 59, Tennessee River flood plain, Lauderdale County, Alabama; Holotype USNM 535599).

jacksoni Morrison *Incidostoma* 1955d, JWAS 45(5):158, figs. 13-15 (near Mera, Oriente Province, Ecuador; Holotype USNM 543524).

joseana Morrison *Aroapyrgus* 1946, SMC 106(6)(3850):15, pl. 2, fig. 5; pl. 3, fig. 8 (from a northern tributary of the Rio Mata Puerco estuary, San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542147).

joseana Morrison *Cochliopa* 1946, SMC 106(6)(3850):28, pl. 2, fig. 18; pl. 3, fig. 19 (Rio Mata Puerco, SW San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542173).

joseana Morrison *Detracia* 1946, SMC 106(6)(3850):34, pl. 1, fig. 16 (from under fallen leaves on flood plain of Rio Marina at upper limits of tidal mangrove swamp at its mouth, E side San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542175).

joseana Morrison *Ferrissia (Laevapex)* 1946, SMC 106(6) (3850):39, pl. 1, figs. 5, 6 (from flood plain pools along middle reaches of stream opening into NW mangrove swamp, San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542179).

joseana Morrison *Polymesoda* 1946, SMC 106(6)(3850):44, pl. 1, figs. 12-14 (in drift of Rio Marina mangrove swamp, E side San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542181).

juradoi Morrison *Cochliopina* 1946, SMC 106(6)(3850):20, pl. 2, fig. 8; pl. 3, fig. 10 (from rocks in rapids of stream leading to NW mangrove swamp, San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542154).

kobelti Bartsch and Morrison *Aperostoma (Incidostoma)*

1942b, USNMB 181:190, pl. 25, figs. 7-9; *is Neocyclotus pergrandis* var. Kobelt, 1912 (Cundinamarica, between Bojaca and Tene, Lake of Tedropalo, Colombia; Holotype Berlin Museum 37582).

kompi Morrison *Zetekella* 1946, SMC 106(6)(3850):13, pl. 2, fig. 2; pl. 3, fig. 2 (Rio Mata Puerco and branches, W side San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542140).

kugleri Bartsch and Morrison *Aperostoma (Austrocyclotus)* 1942b, USNMB 181:201, pl. 28, figs. 1-3 (Riecito, District Acosta, Falcon, Venezuela; Holotype USNM 515924).

laddi Morrison *Fijidoma*, 1952a, AMUB: 8 (Lami River, Viti Levu, Fiji Islands; Holotype USNM 597433); *is Fijidoma maculata* (Mousson, 1865) cf. Morrison, 1954d: 384-385.

Lagocyclus Bartsch and Morrison 1942b, USNMB 181:154; type species by original designation *Cyclophorus crosseanus* Hidalgo, 1866.

leai Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:246, pl. 35, figs. 17-19 (Balsas, Peru; Holotype USNM 104451).

leai Bartsch and Morrison *Calaperostoma* 1942b, USNMB 181:165, pl. 21, figs. 17-19; new name for *Cyclostoma striata* Lea, 1834, not *C. striatum* Sowerby, 1825, nor *C. striata* Quoy and Gaimard, 1832).

limafodens Morrison *Probythinella lacustris* 1947d, N 61(1):26, 27; new name for *Paludina emarginata* Küster, 1852, not *Lymnaeus emarginatus* Say.

limellum Bartsch and Morrison *Aperostoma (Austrocyclotus)* 1942b, USNMB 181:197, pl. 27, figs. 6-8 (100-300 M, Rio Cesar Valley, Magdelena, Colombia; Holotype USNM 515906).

Liracyclotus Bartsch and Morrison 1942b, USNMB 181:274; type species by original designation *Cyclostoma psilomitum* Pfeiffer, 1851.

louisianae Morrison *Vioscalba* 1965a, PBSW 78:217, figs. 1, 2 (off Frenier Beach, SW Lake Ponchartrain, Louisiana; Holotype USNM 635627).

malleatum Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:188, pl. 25, figs. 4-6 (no locality; Holotype USNM 317578).

manabense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:239, pl. 34, figs. 10-12 (between Quevedo and Calcata, Manabi, Ecuador; Holotype USNM 524066).

mariae Morrison *Durangonella* 1945c, N 59(1):20, pl. 3, fig. 2 (shell stratum (marl), 1 M below surface of dry lake bed, Tlahuac, 20 KM E of Xochimilco, D.F., Mexico; Holotype USNM 433399).

marshalli Morrison *Micronaias* 1943c, N 57(1):15; new name for *Unio granadensis* Lea, 1868, not Conrad, 1855.

masvense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:254, pl. 37, figs. 1-3 (Cerro Masve, Guayas Province, Ecuador; Holotype USNM 524048).

Megacyclotus Bartsch and Morrison 1942b, USNMB 181: 181; type species by original designation *Cyclostoma ponderosum* Pfeiffer, 1851.

megaplanus Morrison *Amphicyclotus* 1955d, JWAS 45(5): 160, figs. 29-31 (obtained from a peon at Ocozocoantla, Chiapas, Mexico; 600-1000 M, forests of El Ocote [sic]; Holotype USNM 618777).

merrilli Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:263, pl. 38, figs. 19-21 (Brazil; Holotype USNM 58310).

Mexcyclotus Bartsch and Morrison 1942b, USNMB 181:179; type species by original designation *Cyclostoma (Cyclophorus) lutescens* Pfeiffer, 1851.

nanum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:262, pl. 38, figs. 13-15 (coastal range, between sea level - 200 M, between Caracas and Puerto Cabello, Venezuela; Holotype USNM 336128).

naralis Morrison *Cochliopina* 1946, SMC 106(6)(3850):22, pl. 2, fig. 12; pl. 3, fig. 12 (stream flowing into small bay on SW San Jose Island, at landing for U.S. Naval lighthouse, Pearl Islands, Panama; Holotype USNM 542160).

nevadense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:255, pl. 37, figs. 15-17 (8,400 feet, Sierra Nevada Mountains, Venezuela; Holotype USNM 206494).

nicaraguense Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:214, pl. 29, figs. 16-18 (Polvon, Nicaragua; Holotype USNM 524005).

nirafe Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:193, pl. 27, figs. 23-25 (13 KM S of Puerta Santos, Province of Santander del Norte, Colombia; Holotype USNM 380795).

olivaceum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:251, pl. 36, figs. 10-12 (Ecuador; Holotype USNM 524084).

orbis Morrison *Actinonaias carinata* 1942a, BAEB 129:348, 349, 350, 351, 352, 361 (Florence, Alabama; Holotype USNM 84998).

orinocensis Morrison *Castalia* 1943c, N 57(1):14, pl. 5, figs. 1-4 (Orinoco River, Maipures, U.S. Columbia; Holotype USNM 522000).

paezense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:225, pl. 31, figs. 7-9 (valley of Rio Paez, Central Cordilleras, Colombia; Holotype USNM 251169).

paezicolum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:232, pl. 32, figs. 13-15 (2500 M, Rio Paez Valley, Colombia; Holotype USNM 524047).

pailaense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:231, pl. 32, figs. 7-9 (1300 M, Rio Paila Valley, Colombia; Holotype USNM 251171).

palmeri Bartsch and Morrison *Cyrtotoma* 1942b, USNMB 181:172, pl. 22, figs. 1-3 (Gomez Farias, Tamaulipas, Mexico; Holotype USNM 198079).

panamensis Morrison *Neritilia* 1946, SMC 106(6)(3850):5, pl. 1, fig. 2 (along E bank of Rio Juan Diaz, near Las Sabanas Road, E. of Panama City, Panama; Holotype USNM 542133).

parana Morrison *Detracia* 1951a, JWAS 41(1):19, fig. 3 (Amazon River, Para', Brazil; Holotype USNM 594591).

perplexus Morrison *Rugicyclotus* 1955d, JWAS 45(5):154 (Appleton, St. Elizabeth, Jamaica; Holotype USNM 535988).

peruense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:245, pl. 35, figs. 10-12 ("Peru"; Holotype USNM 103999).

pichinchense Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:191, pl. 26, figs. 10-12 (Quito, Ecuador; Holotype USNM 316109).

Pilsbrychilus Morrison, 1952a, AMUB: 7; type species by

monotypy *Pachychilus dalli* Pilsbry, 1896.

pilsbryi Morrison *Durangonella* 1945c, N 59(1):22, pl. 3, fig. 4 (Paso del Rio, Colima, Mexico; Holotype USNM 362551).

pilsbryi Morrison *Strobilops* 1953c, N 67(2):53, pl. 6, figs. 1-3 (Whitby Cave, Bermuda; Holotype USNM 618751).

pittieri Bartsch and Morrison *Calaperostoma* 1942b, USNMB 181:164, pl. 21, figs. 7-9 (Panama; Holotype USNM 523513).

pizarroi Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:193, pl. 26, figs. 7-9 (Maguas, Peru; Wilkes Exploring Expedition; Holotype USNM 20109).

ponchartrainensis Morrison *Mulinia* 1965a, PBSW 78: 222, figs. 5-9 ("Middle Ground", E Lake Ponchartrain, Louisiana; Holotype USNM 635643).

portobellense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:242, pl. 34, figs. 7-9 (Porto Bello, Panama; Holotype USNM 251434).

Pseudiscus Morrison 1942a, BAEB 129:379; type species by original designation *Helicodiscus (Pseudiscus) punctatellus* Morrison, 1942.

Pseudopunctum Morrison 1935, JWAS 25(12):545; type species by original designation *Punctum (Pseudopunctum) smithi* Morrison, 1935.

pulchellum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:263, pl. 38, figs. 16-18 (Brazil; Holotype USNM 524125).

punctatellus Morrison *Helicodiscus (Pseudiscus)* 1942a, BAEB 129:379 (Kentucky Geological Survey Station 74, near White's Cave, near Mammoth Cave, Kentucky; Holotype USNM 535600).

pygmaeum Bartsch and Morrison *Aperostoma (Cyclohidalgoa) translucidum* 1942b, USNMB 181:272, pl. 30, figs. 19-21 (Caratal, Venezuela; Holotype USNM 24026).

redfieldi Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:261, pl. 38, figs. 10-12 (Brazil; Holotype USNM 307399).

reesei Morrison *Paravitrea* 1937, PBSW 50:58, pl. 4, figs. 5-7 (along state highway #3, about 1/4 mile from Virginia boundary, Peters Mountain, Monroe County, West Virginia; Holotype USNM 423599).

roundyi Morrison *Paravitrea* 1935, JWAS 25(12):546, figs. 1-3 (near Dewey, Washington County, Oklahoma; Holotype USNM 365154).

ruatanense Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:207, pl. 28, figs. 7-9 (Ruatan Island, Honduras; Holotype USNM 364702).

Rugicyclotus Morrison 1955d, JWAS 45(5):152; type species by original designation *Rugicyclotus perplexus* Morrison, 1955.

salengoense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:253, pl. 37, figs. 18-20 (Salengo Island, Ecuador; Holotype USNM 104432).

sallei Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:213, pl. 29, figs. 7-9; new name for *Cyclotus (Aperostoma) dysoni minor* von Martens, 1890, not *C. corrugatior minor* Chitty, 1857.

saludensis Morrison *Gastrodonta (Clappiella)* 1937, PBSW 50:58, pl. 4, figs. 1-4 (S side Walnut Mountain, on slope along Fall Creek, tributary of Saluda River, Saluda Mountains, Greenville County, South Carolina; about 1 mile S of North-South Carolina boundary, U.S. Route 25 [sic]; Holotype USNM 423597).

sanjosensis Morrison *Pomacea cumingii* 1946, SMC 106(6) (3850):6, pl. 1, fig. 1 (3 small streams, W side San Jose Island, Pearl Islands, Panama; Holotype USNM 542136).

schermoi Morrison *Cyclochittya* 1955d, JWAS 45(5):154 (Miocene fossil beds, Bowden, Jamaica; Holotype ANSP 82532); *is C. schumoi* Morrison, 1955, q.v.

schumoi Morrison *Cyclochittya* 1955e, N 69(2):72; emendation of *Cyclochittya schermoi* Morrison, 1955.

Semisulcospirinae Morrison, 1952a, AMUB:8, based on *Semisulcospira* Boettger, 1886; *is* Lavigeriinae Thiele, 1929, Morrison, 1954.

Setaeara Morrison, 1952a, AMUB:8; type species by monotypy *Thiara cancellata* Roding, 1798.

simile Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:227, pl. 31, figs. 13-15 ("Bogota", (Colombia) [sic]; Holotype USNM 535989).

sinaloa Morrison *Strobilops* 1953c, N 67(2):54, pl. 6, figs. 4-6 (intercepted by U.S. Dept. of Agriculture at Nogales, Arizona, on succulent plants from Sinaloa, Mexico; Holotype USNM 592719).

sinuosum Morrison *Guianadesma* 1943d, N 57(2):49, pl. 8, figs. 1-6 (Cuyuni River, opposite Kartabo Point, near its junction with the Mazaruni River, Essequibo District, British Guiana; Holotype USNM 536901).

siphonis Bartsch and Morrison *Tomocyclus* 1942b, USNMB 181:145, pl. 19, fig. 5 (Alta Vera Paz, Guatemala: Holotype USNM 162511).

smithi Morrison *Punctum (Pseudopunctum)* 1935, JWAS 25(12):545, figs. 4-7 (near Huntsville, Madison County, Alabama; Holotype USNM 318466a).

stirlingi Bartsch and Morrison *Aperostoma (Incidostoma)* 1942b, USNMB 181:195, pl. 27, figs. 20-22 (Mendez, Upper Paute River, Ecuador; Holotype USNM 516296).

Subcochliopa Morrison 1946, SMC 106(6)(3850):25; type species by original designation *Subcochliopa trochus* Morrison, 1946.

sumichrasti Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:209, pl. 28, figs. 25-27 (Chontales Forest, Nicaragua; Holotype USNM 523674).

totteni Morrison *Hydrobia* 1954a, JWAS 44(1):26; new name for *Turbo minuta* Totten, 1834, not *T. minuta* Brown, 1818, *T. minuta* Michaud, 1828, nor *T. minuta* Woodward, 1833.

tridens Morrison *Pilsbryna* 1935, JWAS 25(12):546, figs. 8-10 (near Strawn, Palo Pinto County, Texas; Holotype USNM 359722).

trochus Morrison *Subcochliopa* 1946, SMC 106(6)(3850):25, pl. 2, fig. 17; pl. 3, fig. 20 (Rio Tribique, Sona, Veraguas Province, Panama; Holotype USNM 542168).

umbilicatum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:224, pl. 31, figs. 1-3 (Bogota, Colombia; Holotype USNM 307428).

utriaense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:240, pl. 34, figs. 4-6 (Puerto Utria, Colombia; Holotype USNM 524068).

valerioi Bartsch and Morrison *Aperostoma (Neocyclotus) dysoni* 1942b, USNMB 181:213, pl. 29, figs. 19-21 (1480 M, Cervantes, Costa Rica; Holotype USNM 524003).

venezuelense Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:247, pl. 35, figs. 20-22 (Venezuela; Holotype USNM 307429).

veracochanum Bartsch and Morrison *Aperostoma (Aperostoma)* 1942b, USNMB 181:229, pl. 31, figs. 16-18 (Maguas, Peru; Holotype USNM 524045).

veraguasensis Morrison *Zetekella* 1946, SMC 106(6)(3850): 12, pl. 2, fig. 1; pl. 3, fig. 1 (Rio Tribique at Sona, Veraguas Province, Panama; Holotype USNM 542139).

Vioscalba Morrison, 1965a, PBSW 78:217; type species by original designation *Vioscalba louisianae* Morrison, 1965a.

virginica Morrison *Retinella (Glyphyalus)* 1937, PBSW 50:55, pl. 4, figs. 14-16 (W slope Blue Ridge, Clarke Co., Virginia, 3 miles W of Trapp, Loudoun Co. [sic]; Holotype USNM 421081).

watlingsi Morrison *Sayella* 1939b, N 53(2):45 (Watling's Island (San Salvador) Bahamas; Holotype USNM 127488).

weberi Morrison *Odostomia* 1965a, PBSW 78:221, fig. 3 (small bay N of Bayou Chene Fleur, N Barataria Bay, Louisiana; Holotype USNM 635638).

wetmorei Bartsch and Morrison *Aperostoma (Neocyclotus)* 1942b, USNMB 181:203, pl. 41, figs. 13-15 (Tierra Nueva, Sierra Negros, Magdalena, Colombia; Holotype USNM 536033).

wetmorei Morrison *Cochliopina* 1946, SMC 106(6)(3850):24, pl. 2, fig. 16; pl. 3, fig. 15 (a little above lowermost rapids to about 1/4 mile upstream, through 3 sets of rapids and pools, Rio Marina, E side San Jose Island, Archipielago de las Perlas, Panama; Holotype USNM 542167).

Zetekella Morrison 1946, SMC 106(6)(3850):11; type species by original designation *Littoridina frenata* Pilsbry, 1935; *is Zetekina* Morrison 1947b, q.v.

zeteki Morrison *Cochliopina* 1946, SMC 106(6)(3850):19, pl. 2, fig. 7; pl. 3, figs. 5, 9 (from leaves and roots along eastern margin of Rio Juan Diaz, just below bridge of Las Sabanas Road, E of Panama City, Panama; Holotype USNM 542152).

zeteki Morrison *Lyrodes* 1946, SMC 106(6)(3850):17, pl. 2, fig. 10 (Pedro Miguel, Canal Zone, Panama; Holotype USNM 542151).

zeteki Morrison *Pomacea* 1946, SMC 106(6)(3850):8, pl. 1, fig. 3 (shallow margin of Chagres River, near Gatuncilla, Panama; Holotype USNM 542137).

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RANGE EXTENSIONS OF FOUR SPECIES OF NUDIBRANCHS ALONG THE PACIFIC COAST OF BAJA CALIFORNIA, MEXICO

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Increased research along the Pacific coast of Baja California is helping to clarify zoogeographic patterns in a region of provincial overlap where there are numerous species-level affinities between adjacent warm temperate and tropical provinces (Bertsch, 1979). This note on the distribution of four species of dorid nudi-

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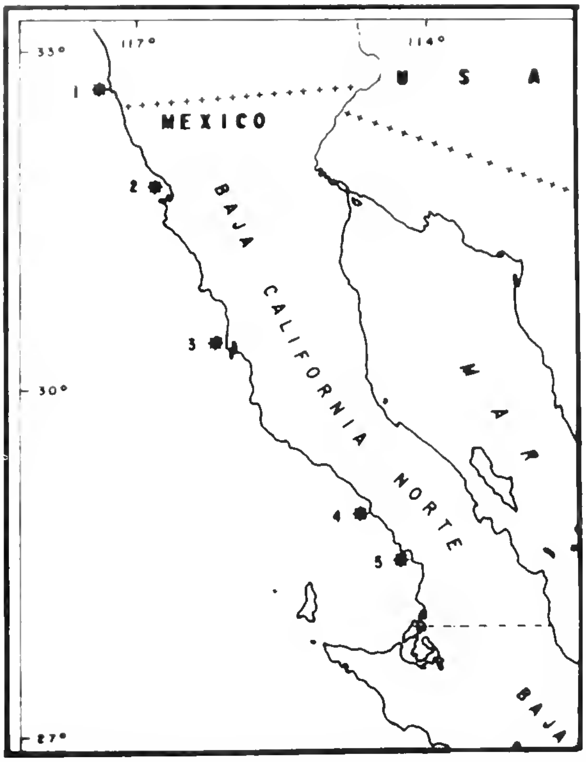

FIG. 1. Map of Baja California, indicating the distribution sites: 1, La Jolla; 2, Ensenada; 3, Cabo San Quintin; 4, Punta Cono; and 5, El Tomatal.

branchs is part of our ongoing series of publications on the flora (Aguilar, 1983; Aguilar & Bertsch, in press), invertebrate fauna (Bertsch, 1983), and comparative opisthobranch zoogeography (Bertsch & Johnson, 1983) of Baja California. Moreover, this paper complements several recent notes (Hamann, 1981; Behrens, 1983; and Bertsch & Smith, 1983) on the distribution of opisthobranchs from southern California (USA) and Baja California (Mexico).

Onchidorididae

Acanthodoris rhodoceras Cockerell in Cockerell & Eliot, 1905

The known range of this species has been reported from Dillon Beach, northern California, to Punta Mesquite (Halfway House), Baja California (Farmer & Collier, 1963; Sphon, 1972; McDonald & Nybakken, 1981: 42).

On 16 June 1983 we found one specimen of *Acanthodoris rhodoceras* (6 mm in total length) underneath an intertidal rock on which were numerous colonies of encrusting bryozoans, on the south side of Punta Cono (28°58′). This is a southward range extension of approximately 440 km.

Triophidae

Triopha catalinae (Cooper, 1863)

Along the eastern Pacific shoreline, the known range of this triophid is from Coghlan Island, Alaska, to Isla Todos Santos, Baja California (Ferreira, 1977:395); it is also known from Japan.

Our finding of one 4 mm long specimen intertidally at El Tomatal (28°29′) 14 June 1983, extends the range of this species over 470 km to the south along the Pacific coast of Baja California.

Triopha maculata MacFarland, 1905

Farmer & Collier (1963) reported this species from Ensenada, Baja California; later Farmer (1967) extended its range southward to Cabo San Quintin. Its northern range limit has recently been extended to Bamfield, Vancouver Island, British Columbia, Canada (Millen, 1983).

We found one 18 mm long individual (orange colored body with white spots) on the north side of Punta Cono, on 16 June 1983. This represents a southern range extension of approximately 210 km.

Dendrodorididae

Dendrodoris nigromaculata (Cockerell, in Cockerell & Eliot, 1905)

The known distribution of this rare porostome is only from its type locality, La Jolla, California (Behrens, 1980: 58; and McDonald & Nybakken, 1981: 52).

We found 5 specimens of *Dendrodoris nigromaculata* intertidally under rocks on 14 June 1983 at El Tomatal. Total lengths of the living animals were 8, 9, 15, 25 and 30 mm. The animals were cream colored; the notum was sprinkled with numerous minute black and white dots, with a row of larger black dots concentrated down each side of the dorsum (dividing it approximately into 3 lengthwise regions); the 6-8 gills were pinkish rose; the notum was margined with a narrow band of pinkish orange.

This is a southerly range extension of approximately 600 kms, and the first definite report of this species from elsewhere than its type locality. (We are aware of the possible synonymy of

the tropical Panamic *Doriopsilla rowena* Marcus & Marcus, 1967, with this species).

Acknowledgements

We are grateful to Dr. Enrique Carrillo, Academic Director of Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, for logistical support; to Roman Lizarraga Arciniega, Director of the Instituto de Investigaciones Oceanologicas, for expediting our field work; to the members of the senior author's graduate course on molluscan ecology (Rodolfo Moreno, Guadalupe Ochoa, Jose Antonio Patino, Ernesto Ripa, Ricardo Santes, and Miguel Angel Tellez); to Gilberto Fuentes G. for drawing the map; and to M. Pamplona and M. Kelley.

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WHAT IS *ERVILIA CALIFORNICA* DALL?

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The fact that *Ervilia californica* Dall, 1916, is not a member of the eastern Pacific Recent molluscan fauna has not come generally to the notice of North American workers. According to Abbott (1974: 493), *E. californica* occurs from San Pedro, California, to Baja California and is "moderately common; just offshore." According to the recently published catalogue of Bernard (1983: 41), this species occurs from 25°N to 34°N in the eastern Pacific.

Ervilia californica, first introduced as a *nomen nudum* in Dall's bivalve checklist (Dall,

1916a: 40), was validated later that year (Dall, 1916b: 414-415). It was based on a single pair (USNM 151419), supposedly collected at San Pedro, California. The catalogue book shows that it was collected and donated by someone named Bridwell, who at the same time gave the USNM some pulmonates from Kansas. The type specimen was first illustrated by Schenck (1945: 516; plt. 66, figs. 19-20).

Rooij-Schuiling (1972: 60-62; 1973: 236-237) has shown that the unique type specimen of *Ervilia californica* is indistinguishable from the western Atlantic *E. nitens* (Montagu, 1808: 165-166), and she termed the eastern Pacific locality of the former "dubious" (p. 239). I would agree with her about the type specimen, which I have recently studied. Moreover, I have examined all of the large collections of eastern Pacific bivalves, and not one has this species from western North America, the only specimens so labeled being such other genera as *Cumingia*. The type was undoubtedly a mislabeled Florida specimen.

So, here is a bivalve species that can safely be removed from our checklists.

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RANGE EXTENSIONS OF SOME INTRODUCED LAND MOLLUSKS IN THE BAHAMA ISLANDS, WITH FIRST REPORTS FOR FOUR SPECIES[1]

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ABSTRACT

Range extensions in the Bahama Islands for 8 species of introduced land snails are reported. Four additional species are recorded from the Bahama Islands for the first time. These species probably were introduced by commerce from southern Florida and Cuba.

During the past 90 years, several surveys have been published on the land mollusks of the Bahama Islands (Bendall, 1895; Dall 1905, 1905a; Clapp 1913; Pilsbry 1930; Clench 1933, 1937, 1938, 1938a, 1940, 1942, 1952, 1959, 1961, 1963). These surveys usually were conducted on a single island or island-group. However, they can be used to construct a picture of the ranges of the taxa found on most of the major islands of the Bahamas.

There are several prominent adventive taxa that have appeared on these lists, including 4 large (to 25 mm) and easily distinguishable species: *Orthalicus undatus* (Bruguière),

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Zachrysia provisoria (Pfeiffer), *Subulina octona* (Bruguière), and *Bulimulus sepulcralis* (Poey). Recent collections (1980, 1981, 1983) in the Bahama Islands indicate that these species have extended their ranges since publication of the latest surveys. The sizes and distinctive appearances of these taxa make it unlikely that their presence was overlooked during previous surveys.

Four other widespread adventive taxa are present in the Bahama Islands. These are *Lamellaxis gracilis* (Hutton), *L. micra* (Orbigny), *Opeas pumilum* (Pfeiffer), and *Hawaiia minuscula* (Binney), all of which have been reported from these islands in the past. In contrast to *Zachrysia*, *Orthalicus* and *Bulimulus*, these species are very small (2-10 mm) and could easily have been overlooked by collectors during earlier surveys. Thus, it is not possible to determine whether the ranges of these species have been extended or simply have become better understood.

In addition, four other species are reported from the Bahama Islands for the first time. Two of these, *Praticolella griseola* (Pfeiffer) and *Drymaeus multilineatus* (Say), are common in south Florida, particularly on nursery stock. It is likely that these species were introduced to the Bahamas on such nursery stock because they appear to be restricted to landscaped areas. The Bahamian government does not require inspection of individual shipments of plants from Florida (U.S.D.A. 1971), which increases the likelihood of this mode of introduction.

The third of these taxa, *Macroceramus canimarensis canimarensis* (Pfeiffer), is a native of eastern Cuba. Its relatively large size (to 20 mm) indicates that it probably was not overlooked during previous surveys and therefore was introduced since the work of Clench (1938) on these islands. The restriction of this species to the area of Marsh Harbour, Great Abaco Island, also supports recent introduction, possibly by commerce.

The fourth species reported for the first time from the Bahama Islands is *Lamellaxis mauritianus* (Pfeiffer). This small (9-12 mm) species is distributed widely throughout the tropics and greenhouses of both hemispheres and so its presence in the Bahama Islands is not unexpected. As with other small achatinids, this species is easily misidentified. Therefore, it is difficult to establish when this species might have been introduced. It also could have been overlooked by collectors because of its small size.

The collections on which this study is based were made on Great and Little Abaco Islands in 1980 by the author, and on North Andros Island in 1981 by Richard Franz, Florida State Museum. Additional records were gathered by an examination of the collections housed at the Florida State Museum, Gainesville, Florida.

ACHATINIDAE

Subulina octona (Bruguière)

Bulimus octonus Bruguière, 1792, Encycl. Meth. 1:325.

This species is one of the most widespread of the adventitious taxa. It is a native of the Caribbean and was originally described from Guadeloupe Island and Santo Domingo. It has been introduced into such remote localities as Ceylon, Africa, the East Indies, Pennsylvania, and southern Florida (Pilsbry, 1946). *Subulina octona* has been reported in the Bahama Islands from Nassau, New Providence Island (J. J. Brown, 1886; W. Bendall, 1895), Arthurs Town, Cat Island (Clench 1938a), Foxtown, Little Abaco Island (Clench 1938), and Rock South, Eleuthera Island (Clench 1952). Collections made in 1980 and 1981 indicate that this snail is present at Marsh Harbour, Great Abaco Island, and at Owenstown, North Andros Island. In addition, there is an undated lot collected at Mastic Point, North Andros Island by L. D. Thompson. *S. octona* is represented also in the Florida State Museum collected by 1 lot collected on San Salvador Island in 1963 by D. R. Paulson.

Specimens Examined – GREAT ABACO ISLAND: Marsh Harbour (UF 40225, 40184, 40221). LITTLE ABACO ISLAND: Foxtown (UF 40185). NEW PROVIDENCE ISLAND: Nassau (UF 20090, 20092). NORTH ANDROS ISLAND: Owenstown (UF 35767); Mastic Point (UF 20091). SAN SALVADOR ISLAND: 3.4 miles south of Cockburn Town (UF 39284).

Lamellaxis gracilis (Hutton)

Bulimus gracilis Hutton, 1834, Jour. Asiatic Soc. Bengal 3:93.

This species probably is the most widely distributed land snail, having been carried by man throughout the tropical regions of the world (Pilsbry and Bequaert, 1927). It even has

become established in European greenhouses. In the Bahamas it has been reported at West End on Grand Bahama Island (Clench 1938), Arthurs Town and Orange Creek, Cat Island (Clench 1938a), Bannermantown and Rock Sound, Eleuthera Island (Clench 1952), 2 miles east of Matthew Town, Great Inagua Island (Clench 1959), and Marine Farm Hill, Cripple Hill, and Church Grove, Crooked Island (Clench 1963). Dall (1905) reported *Opeas subula* Pfeiffer (=*gracilis*) from Nassau, New Providence Island, and from Marsh Harbour, Great Abaco Island. Recent collections indicate that *L. gracilis* is also present at Foxtown, Little Abaco Island, where it was collected for the first time.

Specimens Examined – LITTLE ABACO ISLAND: Foxtown (UF 40229, 39167). NEW PROVIDENCE: Nassau (UF 1209).

Lamellaxis micra (Orbigny)

Helix micra Orbigny, 1835, Magazin de Zool. p. 9.

Lamellaxis micra was originally described from Bolivia but has a wide range throughout northern South America to Mexico and the West Indies (Pilsbry 1946). This species also has been introduced into Florida (Burch 1962). In the Bahama Islands, Dall (1905) reported *L. micra* from Nassau, New Providence Island, as well as from Mangrove Cay, North Andros, and Nassau, New Providence, under the name *Opeas octonoides* C. B. Adams (=*micra*). *Lamellaxis micra* has been reported also from Abraham's Bay, Mariguana Island (Clench 1937), and Clarence Town, Long Island (Clench 1940). Specimens in the Florida State Museum collection confirm the presence of this species on North Andros and indicate that *L. micra* also is found on San Salvadore Island (1964). It was collected recently on Little Abaco Island (1980) as well.

Specimens Examined – LITTLE ABACO ISLAND: Foxtown (UF 39184). NORTH ANDROS ISLAND: Nicholas Town (UF 7504); Mastic Point (UF 40331). NEW PROVIDENCE: Nassau (UF 40330). SAN SALVADOR ISLAND: 3.4 miles south of Cockburn Town (UF 39282).

Lamellaxis mauritianus (Pfeiffer)

Bulimus mauritianus Pfeiffer, 1852, Proc. Zool. Soc. London 20:150.

The type locality for this species is Mauritius (Pilsbry 1906). However, this taxon had been spread by commerce throughout the tropics to such a degree at the time it was described that its original range could not be discerned (Pilsbry 1946). This species has never been reported from the Bahama Islands before. However, the small size (9-12 mm) of the shell and the similarity of shape to other adventitious achatinids make this species easy to overlook. It is reported here from Nassau, New Providence Island, but may be much more widely spread in the islands.

Specimens Examined – NEW PROVIDENCE: Nassau (UF 40329).

Opeas pumilum (Pfeiffer)

Bulimus pumilus Pfeiffer, 1840, Archiv. f. Naturgeschichte 1:252.

This snail is a native of the New World tropics and has been introduced widely in greenhouses in the northern United States and England (Pilsbry 1946). It is small and has frequently been misidentified as one of the other achatinids. *O. pumilum* has been reported from North Andros Island (Pilsbry 1930) and South Bimini Island (Clench 1942). It is now present on the Carter Cays, Powell Cay, and Great Abaco Island.

Specimens Examined – CARTER CAYS: Little Carter Cay (UF 39142, 39149). GREAT ABACO ISLAND: Marsh Harbour (UF 39206); Powell Cay (UF 39229, 39214). NORTH ANDROS ISLAND: Mastic Point (UF 18602).

CAMAENIDAE

Zachrysia provisoria (Pfeiffer)

Helix provisoria Pfeiffer, 1858, Malak. Blätt. 5:39.

This is a large snail (25-30 mm) that is native to Cuba. It was introduced into southern Florida prior to 1918 (G. H. Clapp, 1919) where it is proving to be an agricultural pest on nursery stock in Dade County. *Z. provisoria* also has been introduced into the Virgin Islands, on the island of St. Croix. This species has been reported in the Bahama Islands from Nassau, New Providence Island (J. J. Brown, 1886; Bendall, 1895), and Nield's Place, Little Abaco Island (Dall 1905). Dall (1905a) reported it from "Abaco" but gave no further locality data for these islands. *Z. provisoria* has been reported also from Foxtown, Little Abaco Island, and Great Abaco Island (Clench 1938), and Eleuthera Island (Clench 1938, 1952). The continuing

presence of this species on both Great and Little Abaco Islands was confirmed by collections made in 1980. It occurs in great numbers in moist shady areas near human habitation. *Z. provisoria* was collected also on Grand Bahama Island in 1963 by M. L. Paulson and on North Andros Island in 1981 by R. Franz. Both of these collections constitute new records for the species in the Bahama Islands. R. T. Abbott (*in litt.*) informs me that he observed living specimens in Dec. 1983 at Green Turtle Cay, Marsh Harbour, Hopetown, Abaco Island, and Spanish Wells, Eleuthera Island, and Nassau, New Providence.

Specimens Examined – GRAND BAHAMA ISLAND: Freeport (Marco City) (UF 39433). GREAT ABACO ISLAND: Marsh Harbour (UF 39354). LITTLE ABACO ISLAND: Foxtown (UF 40203, 40208, 40209, 40211); Hawksbill Cays (UF 40183). NEW PROVIDENCE: Nassau (UF 1332, 7602, 527, 529, 16600). NORTH ANDROS ISLAND: Owenstown (UF 35797, 35740).

POLYGYRIDAE

Praticolella griseola (Pfeiffer)

Helix griseola Pfeiffer, 1841, Symbol. Hist. Hel. 1:41.

This species has not been recorded before from the Bahama Islands. It is a native of Central America, with a range extending from Nicaragua to Brownsville, Texas. *Praticolella griseola* has been introduced into Hispaniola, Cuba, southern Florida, and the Cayman Islands. It has recently been collected in the Bahama Islands at Marsh Harbour, Great Abaco Island (1980). It also has been reported to occur on North Andros Island (E. P. Keferl, personal communication).

Specimens Examined – GREAT ABACO ISLAND: Marsh Harbour (UF 40189, 40222).

BULIMULIDAE

Bulimulus sepulcralis (Poey)

Bulimus sepulcralis Poey, 1853, Mem. Hist. Nat. Cuba. 1:203.

This snail was described originally from Havana, Cuba, and was first reported in the Bahama Islands from Nassau, New Providence Island (J. J. Brown, 1886 and Bendall, 1895). Clench (1938, 1952) reported this species from Settlement Point, Grand Bahama Island, and from Eleuthera Island, commenting that in each case it represented an introduction. Recent collections show that *B. sepulcralis* is found also on Great Abaco Island, living under rocks in damp areas. Bendall reported it as "very common on damp ground."

Specimens Examined – ELEUTHERA ISLAND: Spanish Wells (UF 18303), GREAT ABACO ISLAND: Marsh Harbour (UF 40226, 40219, 40188, 40226), NEW PROVIDENCE ISLAND: Nassau (UF 36643, 40235); Windsor Field (UF 40236); unspecified (UF 1185, 16604, 18304).

Drymaeus multilineatus (Say)

Bulimus multilineatus Say, 1825, J. Acad. Nat. Sci. Phila. 5:120.

This species is distributed throughout the Caribbean, being found in Colombia, Venezuela, Curacoa, Yucatan, Cuba, and the southern half of Florida (Pilsbry 1946). It has not been recorded before from the Bahama Islands. In 1981, 2 specimens were collected on a hibiscus bush in Androstown, North Andros Island, by R. Franz. This species is not known to be an adventitious taxon but it has been introduced to the Pacific island of Guam (C. Christensen, personal communication).

Specimens Examined – NORTH ANDROS ISLAND: Androstown (UF 35738).

Orthalicus undatus (Bruguière)

Bulimus undatus Bruguière, 1792. Encycl. Meth. Vers. 1:320.

This large tree snail, reaching a length of about 50 mm, has a history of being introduced, probably from Trinidad, to various parts of the West Indies, including Jamaica, the Lesser Antilles and the Bahamas (Pilsbry, 1899, p. 106). It occurs near human habitation and may be found on walls, the sides of houses and in garden trees, especially during rainy periods. It was first reported (as *zebra* Brug.) in the Bahamas from New Providence Island by W. Bendall in 1895 and later from Andros Island by J. J. White probably in the 1880's (Pilsbry, 1899, p. 107). Barbara Mason of Santa Ana, California, found a live specimen in Spanish Wells, northern Eleuthera, in December 1983; and at the same time and place, local residents informed R. T. Abbott that they had been seeing them common-

ly in their backyards for at least the last 20 years.

Specimens Examined – ELEUTHERA ISLAND: Spanish Wells, R. T. Abbott, 1983 (UF uncataloged).

ZONITIDAE

Hawaiia minuscula (Binney)

Helix minuscula Binney, 1840, Boston J. Nat. Hist. 3:435.

Hawaiia minuscula is widely distributed across the United States and Central America. It has been carried apparently by commerce to several Pacific islands, Japan, the West Indies, and to greenhouses in Great Britain (Pilsbry 1946). This species was reported first in the Bahama Islands from New Providence (Dall 1905). It is found also on North Andros Island in the area of Lake Forsyth (Pilsbry 1930) and is represented in the Florida State Museum collections by a lot collected in Androstown, North Andros Island, in 1981. *H. minuscula* is recorded here for the first time from Great Abaco Island, where it was collected in 1982 by D. M. Biggar, Jr. The small size of this species (2-5 mm) allows it to be easily overlooked by collectors. It is difficult to ascertain whether or not it represents a true introduction because of this possibility of accidental neglect.

Specimens Examined – GREAT ABACO ISLAND: Dundastown (UF 39319), Marsh Harbour (UF 39351). NORTH ANDROS ISLAND: Androstown Airport (UF 39297).

UROCOPTIDAE

Macroceramus canimarensis canimarensis (Pfeiffer)

Bulimus canimensis Pfeiffer, 1839, Archiv. f. Naturg. 1:351 (typographical error; emended to *canimarensis* Pfeiffer, in Philippi, 1843.

This species is native to central and eastern Cuba (Pilsbry 1904). It has not been recorded before from the Bahama Islands. *M. c. canimarensis* was collected first on Great Abaco Island in 1982 by D. M. Biggar, Jr. It appears to be limited to areas near Marsh Harbour where other Cuban snails have been introduced.

Specimens Examined – GREAT ABACO ISLAND: Dundastown (UF 39315); Marsh Harbour (UF 39271).

Acknowledgments

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RIB NUMBER AND SHELL COLOR IN HYBRIDIZED SUBSPECIES OF THE ATLANTIC BAY SCALLOP, *ARGOPECTEN IRRADIANS*[1]

John Kraeuter[2], **Laura Adamkewicz**[3], **Michael Castagna**, **Robert Wall**, and **Richard Karney**[4]

ABSTRACT

Bay scallops, Argopecten irradians *(Lamarck), from populations with low rib number (Texas) and high rib number (Virginia) were bred separately and also hybridized. The results suggest that rib number is under genetic control and that the two populations are genetically differentiated. Scallops taken from a population polymorphic for shell color (Massachusetts) were bred in groups, each group containing a single color. The results suggest that color is also under genetic control and is not strongly influenced by the environment.*

The Bay Scallop, *Argopecten irradians* (Lamarck), occurs in disjunct populations from Massachusetts to the Texas gulf coast. Three subspecies are recognized: *Argopecten irradians irradians* (Lamarck) from Massachusetts to New Jersey, *Argopecten irradians concentricus* (Say) from New Jersey to Louisiana, and *Argopecten irradians amplicostatus* (Dall) from Galveston to Laguna Madre along the Texas coast (Waller, 1969). Clarke (1965) has suggested that the Texas populations should be considered a separate species distinguished by fewer ribs per shell and more inflated valves than other populations. However, the genetic basis, if any, of these shell characteristics is not known. Struhsaker (1968) has found a genetic basis for shell sculpture in the gastropod *Littorina picta* and Staiger (1957) has demonstrated that shell thickness is genetically controlled in the gastropod *Nucella lapillus* (formerly *Purpura lapillus*).

The subspecies *A. i. irradians* is known to be polymorphic for shell color and pattern. One or both valves can be orange, brown, yellow or white and the color can be distributed as solid, banded or mottled. Shell color has been shown to be controlled by a single gene in the mussel *Mytilus edulis* (Innes and Haley, 1977) as has the color pattern *notata* in the clam *Mercenaria mercenaria* (Chanley, 1961). However, diet is also known to influence shell color and banding in some mollusks (Moore, 1936; Underwood and Creese, 1976). Genetic and environmental influences on shell color have not been investigated in *A. irradians.*

When shell characteristics are used to distinguish populations of mollusks, information on the genetic control of the trait is very desirable. We report the results of several experimental crosses made to investigate the inheritance of rib number and shell color in *A. irradians.*

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Materials and Methods

All the adult scallops were mated and their offspring reared at the Virginia Institute of Marine Science (VIMS) Eastern Shore Laboratory using methods described by Castagna (1975). For the investigation of rib number, scallops were imported from Laguna Madre, Texas. These were mated among themselves (Texas cross) as were animals from a native Virginia stock (Virginia cross). Individuals from the two stocks were mated to produce an F_1 (hybrid cross). All three matings were made at the same time and all offspring were the same age when scored for rib number. During the growth period, conditions were kept as uniform as possible.

Scallops for the shell-color matings were obtained from Sengekontacket Pond on Martha's Vineyard, Massachusetts. The animals were sorted into three groups based on the colors of their top and bottom valves: orange top-orange bottom (o/o, 18 scallops), brown-white (b/w, 21 scallops), and white-white (w/w, 32 scallops). Each group was mass spawned. When the offspring were 1.5 to 2.0 cm long, they were scored for top and bottom valve color.

Results and Discussion

Table 1 shows the distribution of shell colors among the offspring of each color group. As expected in mass crosses of wild-caught individuals, no Mendelian ratios occur. However, the distribution of colors was completely different in each of the matings and no single parental phenotype produced the entire range of colors among its offspring. All of the white offspring and none of the orange ones came from the mating of white-shelled parents. One phenotype (both valves brown), that was not present in any of the parents, appeared among the progeny of all three crosses and the phenotype "striped yellow", also not present in the parents, appeared in the b/w cross.

These results are not compatible with any hypothesis that the environment, particularly the diet, has a strong influence on shell color. All three crosses were reared in natural sea water from a common source. Furthermore, the offspring were reared in Virginia where the native population is not polymorphic for these shell colors. The results are compatible with the hypothesis that shell color is genetically controlled, possibly by only a few genes. Because none of the parental phenotypes produced uniform progeny none of the three phenotypes tested can represent a single, homozygous genotype.

Table 2 presents the data on number of ribs per top valve in the Texas and Virginia crosses and their F_1 hybrid. The Texas and Virginia offspring were distinctly different with no overlap in number of ribs. The maximum number of ribs for a Texas shell was 18 and the minimum for a Virginia shell was 19. The mean rib number for the Texas scallops was 15.96 and for the Virginia scallops it was 20.39. Clearly the hybrid cross was intermediate both in range of rib numbers, 17 to 21, and in mean rib number, 18.90. However, the hybrid mean of 18.90 differed

TABLE 1. Distribution of shell colors in offspring of mass matings of single colors. Colors are o = orange, b = brown, w = white, y = yellow. Top valve is listed first, bottom valve second.

Parental Phenotype	Offspring Phenotypes o/o	b/b	b/w	w/w	y/y	TOTAL
o/o	1671	413	197	0	0	2281
b/w	30	143	760	0	25	958
w/w	0	124	137	949	0	1210

TABLE 2. Distribution of rib number on the top valves of *A. irradians* from experimental crosses.

Number of Ribs	CROSS Texas	Hybrid	Virginia
14	8		
15	25		
16	34		
17	29	7	
18	4	28	
19		37	25
20		24	36
21		4	23
22			9
23			5
24			2
TOTAL ANIMALS	100	100	100
MEAN	15.96	18.90	20.39
VARIANCE	1.029	0.960	1.473
STD. ERROR OF MEAN	0.101	0.098	0.121

significantly from the mid-parent value of 18.18 and was closer to the Virginia mean than to the Texas mean. A one-way analysis of variance showed a highly significant difference in rib number among the three crosses (F ratio = 440 with d.f. 2 and 297, error mean square = 1.15, $p<0.0001$). These results are exactly what one expects for a polygenic trait when two genetically distinct strains, or in this case subspecies, are crossed (Falconer, 1981).

An examination of size differences among the three crosses also supports the hypothesis that differences in rib number are genetically determined. Figure 1 shows the mean and range of shell length (lip to hinge) for each of the rib numbers in each of the crosses. The three crosses were significantly different in shell length with the Texas scallops smallest and the hybrids exactly intermediate (mid-parent = 32.3). A one-way analysis of variance of shell length among crosses gave an F ratio of 40 with 2 and 169 degrees of freedom, $p < 0.001$. However, when each cross was examined separately, there was no tendency for size to increase with increasing rib number. The regression coefficient of size on rib number was not significantly different from zero in any of the three crosses. One cannot conclude that the Texas progeny have low rib numbers merely because they are small.

Interpretation of the size differences themselves is less clear. The intermediate performance of the hybrid cross does suggest that the differences among the crosses is genetic and additive. However, the stocks may have differed in genes for temperature adaptation rather than in genes for growth rate. The Texas parents were native to an area of higher water temperature than that in which their offspring were raised. Rearing offspring at a temperature other than that to which their parents were adapted has been shown to affect growth rate in clams (Menzel, 1962).

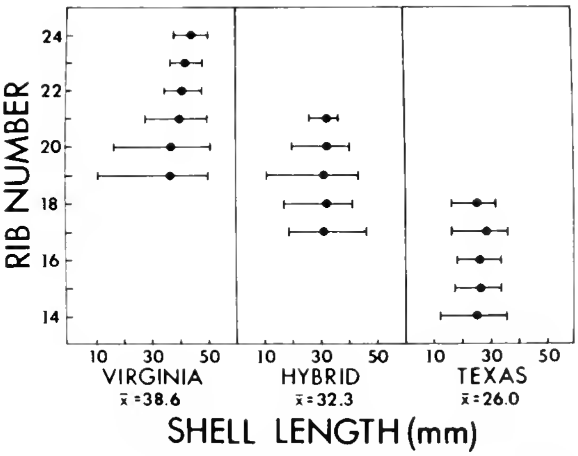

FIG. 1. The range of shell lengths and the mean for each rib number class in *Argopecten irradians*. The Virginia, Hybrid and Texas scallops are the same as those described in Table 2.

Conclusions

From this study, shell color appears to be under genetic control, to be insensitive to the environment and, therefore, to be a valid character for distinguishing between individuals and between populations. Rib number also appears to be genetically controlled and a good character for distinguishing individuals and populations. The data on rib number and shell length show that rib number is a valid characteristic for distinguishing two shells regardless of their absolute sizes. The data also suggest that populations of different geographical origin are genetically differentiated for rib number. The Texas scallops maintained their characteristically lower number of ribs despite being bred and reared in Virginia.

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DEPTH DISTRIBUTION OF SEVEN SPECIES OF GASTROPODS IN DOUGLAS LAKE, MICHIGAN

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ABSTRACT

Variations in the depth distribution and size of operculate and pulmonate gastropod populations were studied in Douglas Lake, Michigan. The species studied, in order of decreasing abundance, were: Helisoma campanulata, Campeloma decisum, Goniobasis livescens, H. anceps, Lymnaea catascopium, Physa integra, *and* P. parkeri. *Peak densities occurred at 0.5m for* G. livescens, *3m for* C. decisum, *6m for* H. campanulata, H. anceps, L. catascopium, *and* P. integra, *and 9m for* P. parkeri. Helisoma campanulata *were found at greater depths as water temperatures rose. Decreases in population size occurred for* H. anceps, L. catascopium, P. integra, *and* P. parkeri *while an increase occurred for* C. decisum.

Snails represent an important component of the benthic fauna of most streams and lakes. However, relatively little information exists either on the distribution of these aquatic gastropods at various depths, or their distribution changes with time. In Michigan, several earlier investigations involved snails from Douglas Lake. These studies include: Baker (1912), Eggleton (1931, 1935), Cheatum (1934), and Clampitt (1973, 1974). In his most recent study, Clampitt collected *Physa integra* on a monthly basis to follow its seasonal migratory cycle. With this exception, studies on the depth distribution of gastropods in Douglas Lake have for the most part been based on single collections at various locations.

Several workers have shown that SCUBA diving can permit direct, quantitative sampling that is useful in various ecological studies (Schmid, 1965; Cavancara, 1972; Harman, 1972; Clampitt, 1973, 1974; Pace *et. al.*, 1979). This study was undertaken using SCUBA to assist in examining the depth distributions and population densities of seven freshwater snail species by making regular collections during an eight-week period.

Materials and Methods

The depth distribution of gastropods was studied by making nine collections between June 20 and August 11, 1982, at a site in Douglas Lake, Cheboygan County, Michigan. An area on East Point (see Figure 1) was selected for study because it supported a diversity of gastropod species through a range of depths. At this site, a sandy shoal with a very gradual decline extends to a depth of 1m, where a fairly sharp drop off begins. The steepness of the slope

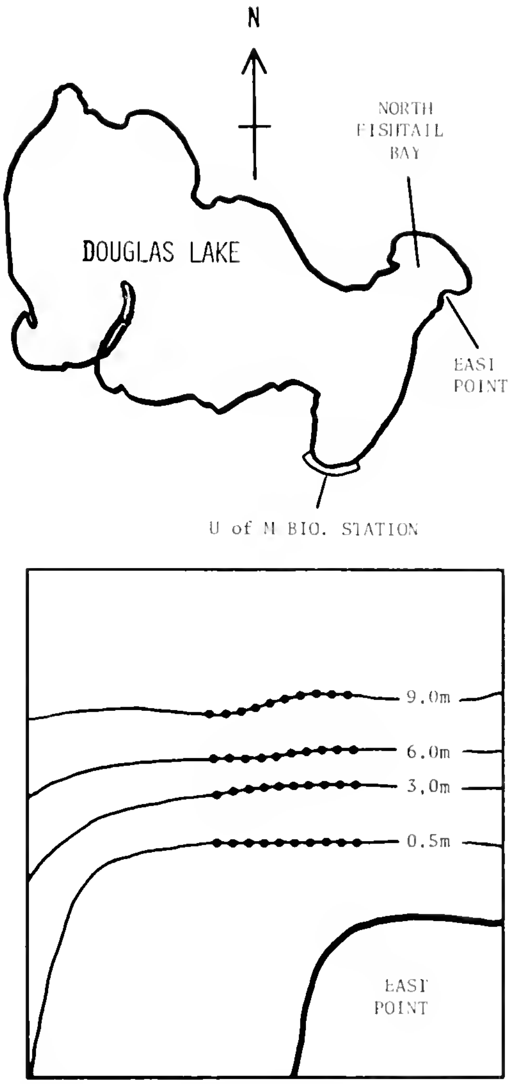

FIG. 1. Map of Douglas Lake with close up of East Point area showing depth contours and sampling transects (indicated by dots).

gradually decreases to the bottom of a fairly level basin 12m deep. With increasing depth, the predominantly sandy bottom gradually becomes covered by a flocculent organic layer. Submerged macrophytes are most common at depths of 2-5m, the predominant species being *Potamogeton sp.*, *Elodea canadensis*, and *Myriophyllum exalbescens*. Though sparse over most of the study area, fairly dense macrophyte growth is present at the east end of the site.

The use of SCUBA facilitated setting up the study site and making collections. Sampling transects along the depth contours of 0.5m, 3m, 6m, and 9m were each marked by ten stakes placed 3m apart. Depths were determined using a calibrated float, line, and weight system. The distances from shore to the centers of the four transects were 21.5, 29.5, 36, and 46m. Two sand filled "hula-hoops" each 0.5m² in area were sequentially placed on either side of each stake, resulting in a 1 m² sample per stake, and a total sample area of 10m² for each depth. All snails on or just beneath the substrate within the hoops were collected manually and placed in prelabeled muslin bags. After examination in the laboratory, all snails were released at the depth at which they were collected. Temperatures were measured at each depth for every collection.

Population densities for each sampling transect were determined by averaging the values for the ten sampling sites. Linear regression analysis was used to determine if statistically significant trends occurred during the study period in depth distribution, population size, and water temperature.

Results

The study area was found to support a number of species of gastropods, which varied in depth distribution and population densities. The following gastropods, in order of decreasing overall abundance, were the focus of this study: *Helisoma campanulata*, *Campeloma decisum*, *Goniobasis livescens*, *H. anceps*, *Lymnaea catascopium*, *Physa integra*, and *P. parkeri*. Other gastropods collected in the area but occurring in smaller numbers were: *L. stagnalis*, *P. sayii*, *Valvata tricarinata*, *Amnicola sp.*, *Gyraulus parvus*, and *Menetus sp*. These species were not included in this study.

The population densities for all nine collections are summarized in Table 1. The largest overall snail population occurred at 6m, followed by 9m, 3m, and 0.5m. The single most abundant snail was *Helisoma campanulata* which had an average density of 18.7 snails/m² at 6m.

The depth distribution of each species, averaged over the nine collections, is shown graphically in Figure 2. The characteristic distribution patterns of each species are worth noting. *Physa integra*, *Lymnaea catascopium*, *Helisoma campanulata*, and *H. anceps* popula-

TABLE 1. Population density of each of the seven snail species by depth, averaged for all nine collections.

Species	Depth 0.5m	3.0m	6.0m	9.0m	Sample Size
	Pop. dens. (snails/m²)				
Physa integra	0.04	0.2	1.4	1.0	241
Physa parkeri	0.01	0.02	0.6	0.8	130
Lymnaea catascopium	0.07	0.2	1.4	1.1	251
Campeloma decisum	0.9	8.7	3.1	4.6	1571
Goniobasis livescens	5.4	5.0	2.8	0.9	1264
Helisoma campanulata	0.1	4.6	18.7	9.6	2972
Helisoma anceps	0.3	2.6	6.4	3.7	1169
Total	623	1921	3097	1957	7598

tions are largest at 6m and have similar distributions patterns. The population of *P. parkeri* increases with depth and is maximal at 9m, while *Campeloma decisum* has a pattern with population size greatest at 3m. The *Goniobasis livescens* population, on the other hand, is largest in shallow water and decreases with depth.

Mean depths were calculated for each species from every collection and were used to determine if changes in depth distribution occurred during the eight-week period over which the collections were made. *Physa integra* and *Helisoma campanulata* both showed a significant ($P<0.05$ and 0.01 respectively) increase in mean depth over the course of the nine collections, indicating that a gradual migration to deeper water was occurring (Fig. 3). *Campeloma decisum* showed no significant trend over the period as a whole but showed a significant ($P<0.01$) increase in depth over the first half of the period and a significant ($P<0.05$) decrease over the second half (Fig. 3). The mean depth for *C. decisum* reached its deepest point on July 14. None of the other four species showed any significant changes in depth distribution during the study.

Population sizes were examined to see if changes occurred for any of the species over the course of the study. Significant ($P<0.01$) decreases occurred for *Physa integra, P. parkeri, Lymnaea catascopium,* and *Helisoma anceps.* A significant ($P<0.01$) decrease occurred for *Campeloma decisum,* while no significant changes occurred for *Goniobasis livescens* or *H. campanulata.*

Analysis of water temperature data showed that a significant warming trend was present over the first six weeks of the study at depths of 0.5m, 3m, and 6m ($P<0.02$, 0.01, and 0.01 respectively). No significant changes in temperature occurred at the 9m depth.

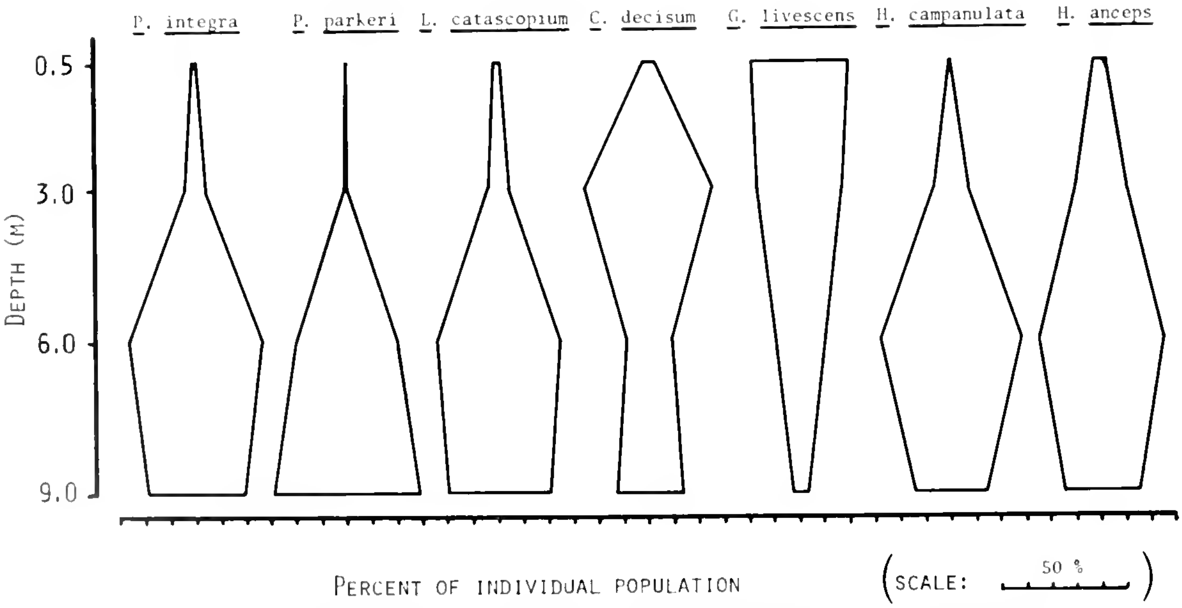

FIG. 2. Depth distribution of each of the seven snail species averaged over all nine collections.

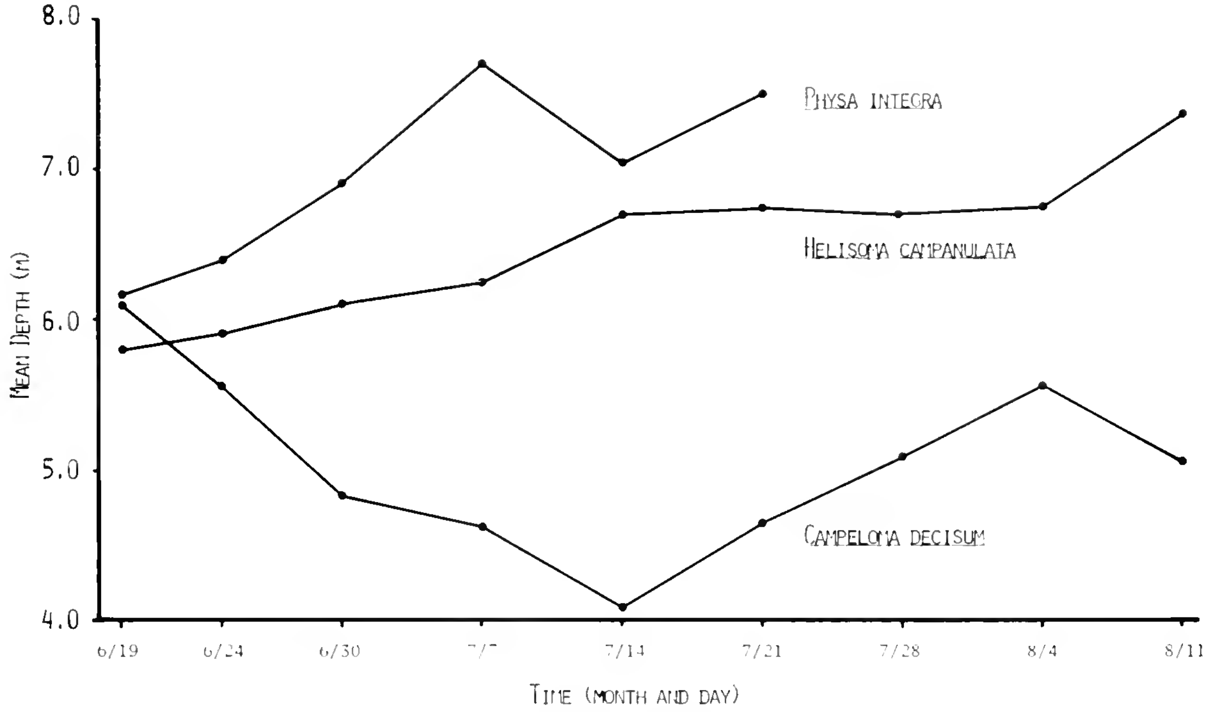

FIG. 3. Changes in mean depth of *Physa integra*, *Helisoma campanulata*, and *Campeloma decisum* during the summer of 1982.

Discussion

The large and diverse populations of snails naturally present in the study area must be the result of appropriate substrate and an abundance of food. Harman (1972) has suggested that gastropod distribution is directly related to substrate type and has categorized snails as to preferred substrates. Of five species common between his study and this one, the preferred substrate of *Lymnaea catascopium*, *Campeloma decisum*, *Goniobasis livescens*, and *Helisoma anceps* was littoral silt and detritus in both studies. While Harman found *Physa integra* to prefer eulittoral silt and detritus, in this study, where the eulittoral zone had a sandy substrate, *P. integra* was most abundant on silt and detritus in the littoral zone. This could suggest that substrate type is a more important environmental factor than water depth in determining the distribution of *P. integra* in a lake.

Clampitt (1973) sampled pulmonate snails at four locations in Douglas Lake in July, 1969, and July, 1970, and reported depth distributions. One of his sampling sites was located very near the site of this study, but he found only *Physa integra*, *Helisoma campanulata* and *H. anceps* to be present and found their depth distribution to vary greatly between the two years he sampled. He found *H. campanulata* to be most abundant at 5.5m in 1970 and this result is similar to that obtained in this study, however, no other similarities were present and considerable changes in the snail population of the area seem to have occurred over the twelve years between the two studies. It appears that populations of snails in Douglas Lake are not stable over long periods. They may vary considerably from year to year, possibly under the influence of such conditions as weather and availability of food.

One example of a short term effect that weather had on a population was witnessed during the study. On July 7, an unusually strong west wind produced waves which dislodged *Goniobasis livescens* from the shoal and an undertow current carried many of them over the drop off to deeper water. Very few *G. livescens* were collected at the 0.5m contour that week but the majority observed below the drop off were ascending the slope. Two weeks after the storm, the *G. livescens* population on the shoal

had returned to its original level. It is not surprising that *G. livescens* is the dominant species at the 0.5m level, since pulmonate snails, with thinner shells and no operculum could probably not withstand such wave action.

A collection transect was not set deeper than 9m because snail numbers decreased rapidly below this depth and virtually no snails were seen below 10m. Temperature in Douglas Lake is highly stratified in the summer, with the thermocline beginning at about 10m. The rapid drop in oxygen levels below the thermocline (Bazin and Saunders, 1971) probably accounts for the lack of gastropods at such depths.

Three snail species showed significant changes in depth distribution over the study period. *Physa integra* and *Helisoma campanulata* both seemed to have moved to deeper water over the course of the summer. Caution must be exercised in interpreting these results, however, since the *Physa integra* population also showed a significantly decline in population size, which in fact reached zero by the end of July. The observed trend in depth distribution could simply be the result of *P. integra* in shallow water dying first, possibly due to the rise in water temperature that was occurring. This idea is supported by the findings of Brown (1979), who showed in a laboratory experiment that though elevated water temperature did not change the overall life history pattern of *P. integra*, it did decrease the average life span. Since the increase in mean depth shown by *H. campanulata* was not accompanied by a population size decrease, it is more likely to be showing an actual migration to deeper water, possibly to avoid gradually warming water near the surface. *Campeloma decisum* showed a significant decrease in mean depth for the first half of the study followed by a increase in depth. An explanation for this observation is not readily apparent. A lack of similar studies in which snail populations were sampled on such a regular basis prevents direct comparison of our results with others.

The decreases in population sizes of *Physa integra*, *P. parkeri*, *Lymnaea catascopium*, and *Helisoma anceps*, probably reflect normal mortality that occurs in the reproductive cycle of these snails. Clampitt (1974) has shown that adult *P. integra* die in July after having mated and laid eggs. Cort, *et al* (1940, 1941) have reported similar life histories for *L. catascopium* and *P. parkeri*. The present study supports the contention that these species are annuals that die after reproducing in early summer.

The population of *Campeloma decisum* showed an increase over the course of the study. It is believed that this is due to the increasing numbers of offspring produced as the breeding season progressed. Since *C. decisum* is not an annual as the pulmonates discussed above, adult mortality does not seem to be high in the summer and a population increase was observed to occur.

Studies of this type in which collections are made on a regular basis can provide much more insight into the life histories of gastropods than single collections from a site. A better understanding of gastropod ecology gained in this way may be of interest not only to ecologists and malacologists, but also to parasitologists who study these snails as intermediate hosts for trematodes.

Acknowledgments

The authors express their thanks to Dr. David Gates (Director) for providing facilities at the University of Michigan Biological Station, and to Dr. Henry van der Schalie and Dr. Eldon Greij for their assistance in reviewing the manuscript.

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FIRST RECORD OF *OCTOPUS DEFILIPPI* VERANY, 1851 IN VENEZUELAN COASTAL WATERS

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ABSTRACT

Octopus defilippi *Verany, 1851, is recorded for the first time in the southeastern Caribbean. The specimens were captured in the coastal waters of Venezuela and are described briefly with an emphasis on its color pattern in a natural habitat.*

In 1979, a long-armed octopod was collected in the shallow waters of the eastern side of the Island of Cubagua, Venezuela. In the summer of 1982, three more long-armed octopods were captured in the Golfo de Cariaco, Venezuela. All four specimens showed affinities with *Octopus defilippi* Verany, 1851.

The collected material was identified utilizing the paper published by Voss (1964), the keys by Roper (1978) and were checked against representative materials at Rosenstiel School of Marine and Atmospheric Science, Miami and the U.S. National Museum of Natural History, Washington, DC. The measurements and indices are those defined by Voss (1963).

Octopus defilippi Verany, 1851

(Fig. 1; Table 1)

Octopus defilippi Verany, 1851: 30; Robson, 1929: 135; Voss, 1964: 554; 1968: 654.

Material examined – 1 male, ML: 38.3 mm, in 2 m taken by hand using SCUBA, Isla de Cubagua, November 3rd, 1979; 1 male, ML: 85.6 mm, in 2.5 m taken by hand using SCUBA, Golfo de Cariaco, June 6th, 1982; 1 male, ML: 66.5 mm, in 2.5 m taken by hand using SCUBA, Golfo de Cariaco, June 6th, 1982; 1 male, ML: 49.8 mm, in 6 m taken by hand using SCUBA, Golfo de Cariaco, August 8th, 1982.

TABLE 1. Mantle length, number of primary gill lamellae, indices of bodily proportions, and spermatophore characteristics for *Octopus defilippi*.

ML	38.3	85.6	66.5	49.8
MWI	44.9	37.6	39.0	45.9
HWI	39.1	21.2	24.5	31.9
ALI	82.8	85.6	86.0	87.8
AWI	15.6	7.4	9.7	11.4
HcAI	35.7	31.7	31.3	40.4
LLI	0.5	0.8	1.0	2.3
CLI	20.0	15.9	13.0	31.0
PLI	26.1	15.4	16.2	20.0
WDI	8.0	6.8	4.9	3.5
SnDI	7.3	4.9	6.6	5.8
Gills	10	11	11	11
SpL	–	9.6	11.3	–
SpLI	–	11.2	16.9	–

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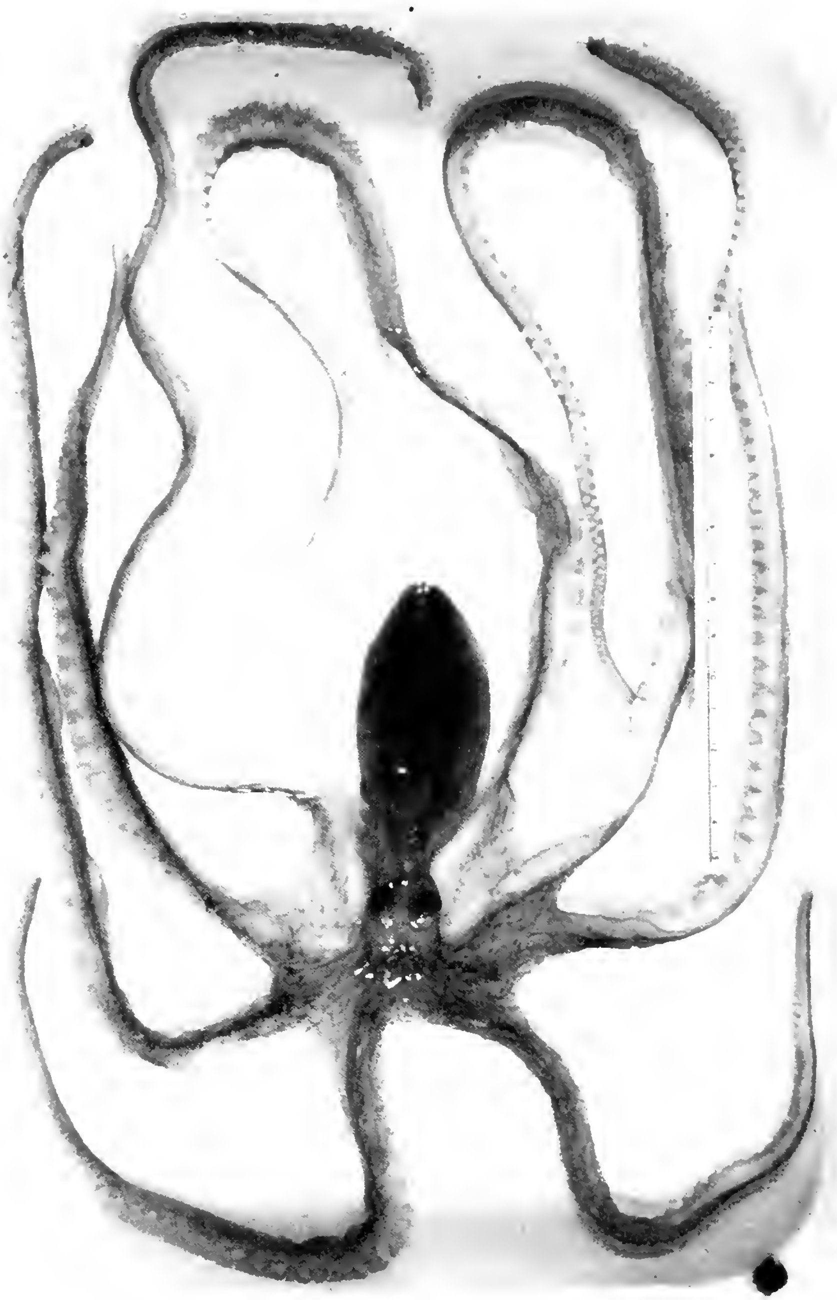

FIG. 1. *Octopus defilippi*. ML : 85.6 mm. Golfo de Cariaco, Venezuela.

Description – The mantle is small, pyriform and strongly constricted in the neck region. The head is wide with very prominent eyes. One long cirrus over each eye on the two larger specimens, but unnoticeable in the smaller ones. The funnel organ has the usual W-shape with the lateral pads shorter than the central ones.

The arms are very long and slender, with very delicate tips. The asymmetry of the arms is evident in all specimens. The first five suckers are in a single row, the remainder are biserial; they are arranged in an alternating pattern in more than half of the length of the arms, and in the remaining part of the arms they are in a parallel

pattern. The small web extends conspicuously up the side of all arms. In the larger specimens, the web on the fourth arm may be as much as 10 mm in its middle portion.

The hectocotylized arm is almost half the size of the other arms. The ligula is very small and the calamus very short. The ligula is slender and tapering with a small slim groove and slightly inrolled edges.

The gill count per outer demibranch is 11 lamellae in the specimens from the Golfo de Cariaco and 10 lamellae in the specimen from Cubagua.

The radula has an A^2 seriation in its rachidian teeth with small ectocones.

The penis is long, slender and tubular with a small round diverticulum at the base of the penial aparatus. All four specimens were sexually mature. The spermatophores are small, with the sperm mass reduced to one fourth of the sperm sac.

The overall skin is light-brown, but it shows dark-brown on the dorsal surface of the mantle where the pigmentation appears as an irregular mesh. In nature, the skin looks rugose and remains that way in very well preserved animals. The ventral surface of the mantle is a plain grayish pink, while the ventral side of the arms is light yellowish cream.

When the animals are observed in their natural habitat a variety of color patterns appears; when undisturbed a greenish brown with grayish traces is present; when disturbed the color of the animal turns to a gray-ash with a black mesh-like pattern. A light-brown color was observed on the surface of the body and the arms. Besides, the arms show a white spot located between two thin, dark-brown, transverse stripes which run along the arms. These white spots are specially noticeable when the animal is resting or at shelter after being disturbed. It was observed that after preserving the animals, the white spots disappeared leaving only the transverse stripes.

Type–Musée d'Histoire Naturelle, Nice. *Type locality*–Pegli, Italy.

Remarks–One specimen captured in the Golfo de Cariaco (ML: 49.8 mm) was found over a bottom of sand and broken shells, while the other three specimens were obtained on *Thalassia* and soft bottom.

This species is obtained for the first time in Venezuelan coastal waters (Fig. 2) and represents the first record for the southeastern Caribbean. The first West Atlantic record occurred in Florida, U.S.A. (Voss, 1964), then in the southwestern Caribbean (Voss, 1968) and lately in Haiti, Cuba, Costa Rica, and Brazil

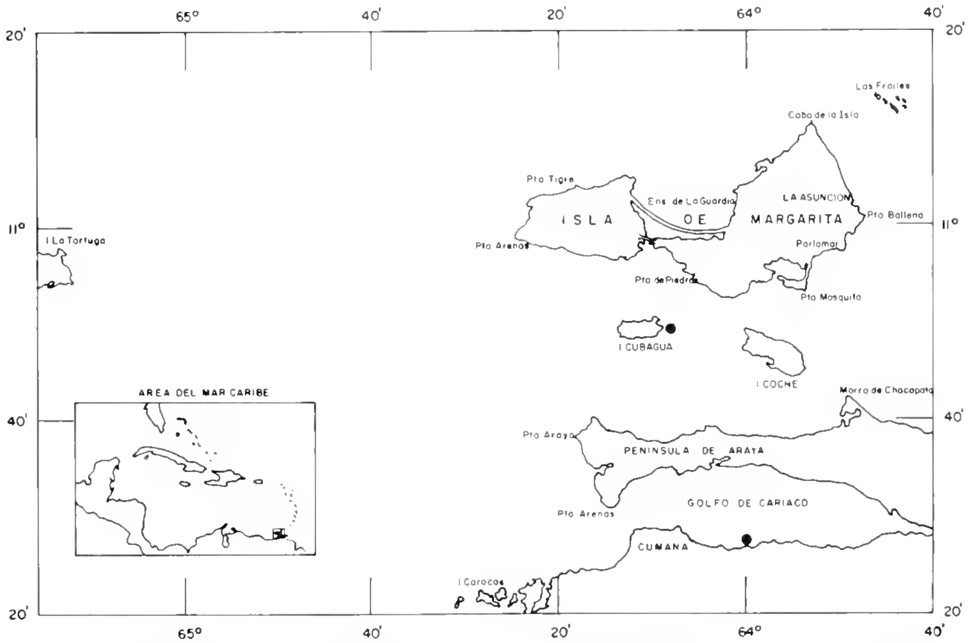

FIG. 2. Map showing localities from where specimens of *Octopus defilippi* were collected.

(Palacio, 1977) and Virgin Islands (Hanlon & Hixon, 1979).

Distribution—Mediterranean Sea; Cabo Verde; vacinity of Dakar; Ghana; Angola; Florida, U.S.A.; Costa Rica; Colombia; Panamá; Virgin Islands; Rio de Janeiro, Brazil; Venezuela.

Acknowledgments

We are grateful to Dr. Gilbert L. Voss and Mrs. Nancy A. Voss for their assistance at Rosenstiel School of Marine and Atmospheric Science, Miami, to Dr. C. F. E. Roper and Mr. Michael Sweeney for their help at the U.S. National Museum of Natural History, Washington, D.C. and to Mrs. Violeta Sanchez and Georgina Spirutova for reading the manuscript.

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FUSINUS LIGHTBOURNI (GASTROPODA: FASCIOLARIIDAE), A NEW SPECIES FROM BERMUDA

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ABSTRACT

Fusinus lightbourni, *n. sp., from 100-200 fms (183-366 m) depths off the south coast of Bermuda differs from* F. frenguellii *(Carcelles, 1953) by its sculpture, lip, and coloration. It grows to about 70 mm while* F. frenguellii *grows to at least 143 mm. The range for* F. ceramidus *(Dall, 1889) is extended to Bermuda.*

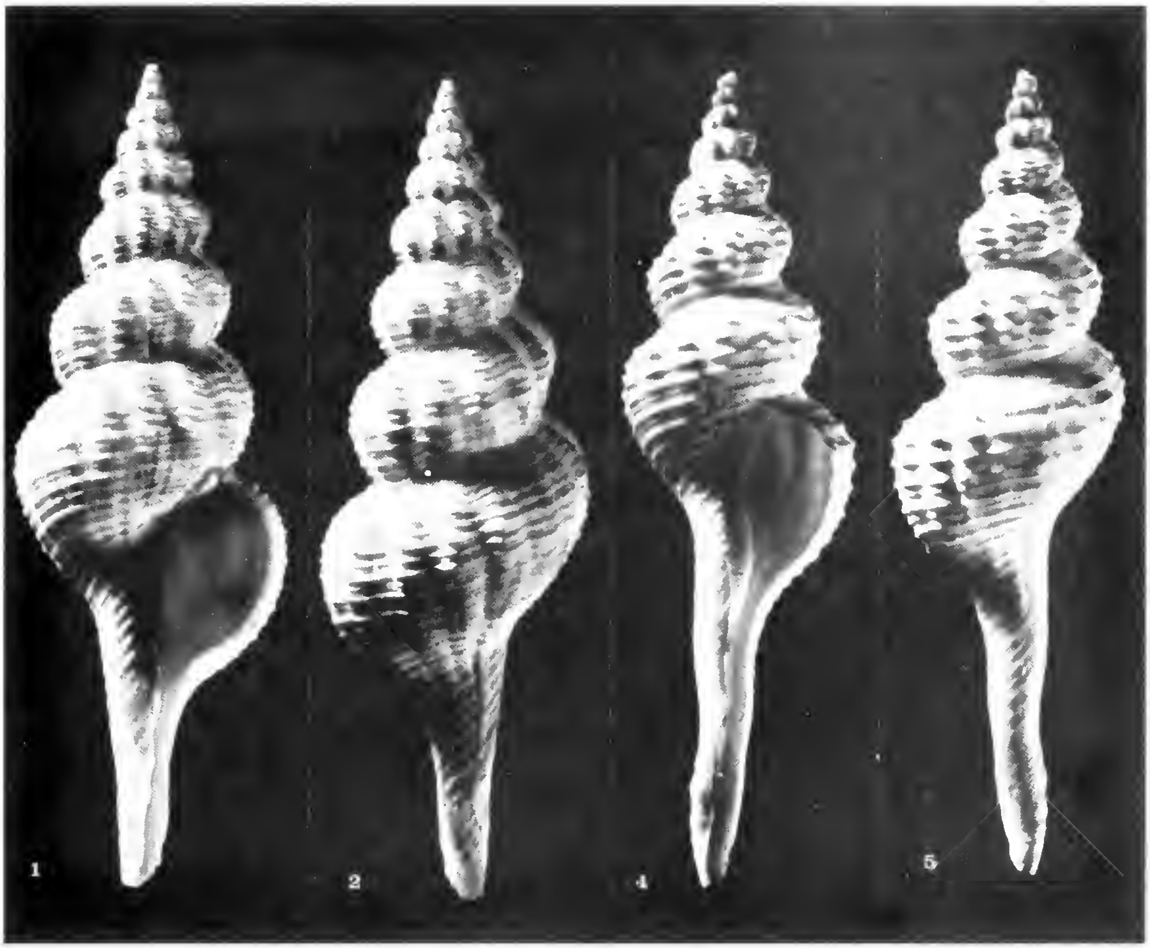
For several years Jack R. H. Lightbourn and Arthur T. Guest have set specially designed mollusk traps in 100-200 fms off the south shore of Bermuda and obtained dead mollusks borne by hermit crabs. Notable among the material collected in this manner are specimens of *Perotrochus quoyanus* (Fisher and Bernardi, 1856) and *Perotrochus adansonianus* (Crosse and Fisher, 1861). During a recent trip to Bermuda the author was able to examine various *Fusinus* specimens obtained in this matter. One lot represents a range extension of a known taxon; another shell represents a new taxon described herein.

Specimens of the new species are deposited in the collections of the Delaware Museum of Natural History (DMNH), Academy of Natural Sciences of Philadelphia (ANSP), and the United States National Museum in Washington (USNM). Additional specimens are in the Jack Lightbourn collection and the collection of the author.

Fusinus lightbourni, *new species*

(Figures 1-3)

Description: Shell moderately large for the genus, 45 mm-70 mm. Profile somewhat inflated, fusiform, with about 10 whorls. Embryonic whorls are smooth, quite pointed, and waxy white in color (DMNH 154462, 66 mm). Teleconch bears strong axial ribs which are not evanescent on the body whorl. Later whorls bear 13 or 14 such ribs. These ribs present a slightly angular profile, being crossed by about



FIGS. 1 and 2, *Fusinus lightbourni*, n. sp., holotype. 61 mm DMNH 154461.
FIGS. 4 and 5, *F. frenguellii* (Carcelles, 1953) 71 mm, by fishermen in 30 fms off Rio de Janeiro, Brazil, December 1968; author's collection.

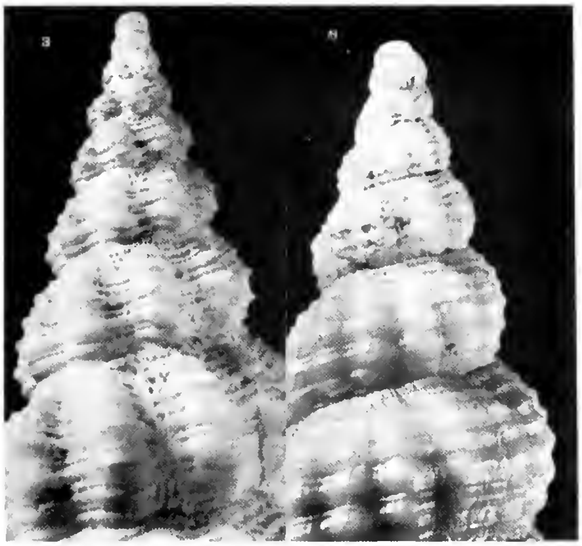
10 strong spiral lines, the two strongest on the shoulder giving the angular appearance to the profile. Between these 10 stronger spiral lines are finer lines. These in turn are crossed by very fine axial lines giving the surface of the shell between the axial ribs and strong lines the texture of linen. The aperture is ovate, pinched at the anterior and posterior ends. The parietal callous is extended forming sharp, thin lamina on the inner lip along the columellar border of the aperture. The inner surface of the outer lip is calloused and strongly denticulate with about 16 lirae. Base and anterior siphonal canal are straight and slender, being about one half of the total length of the shell. The shell is white with pale-brown bands of color just before and just after the suture. In some specimens the canal is recurved. The operculum and soft parts are unknown.

Holotype: Length 61 mm, crabbed specimen from a fish pot in 100-120 fms taken 1½ miles due south of Gurnet Rock, south shore of Bermuda, summer 1979 (DMNH 154461).

Other Material: 3 paratypes DMNH 154462 (46 mm, 61 mm, 66 mm), 1 paratype ANSP 356701 (60 mm), 3 paratypes USNM 819199 (54 mm, 63 mm, 65 mm), and 3 paratypes in the author's collection (51 mm, 59 mm, 70.5 mm). All paratypes from the same locality as the holotype, but in different collecting hauls and depths down to 200 fms.

Etymology: The species is named for Jack R. H. Lightbourn who has done much to extend our knowledge of the Bermudian molluscan fauna.

lightbourni	*frenguellii*
1½ whorl small pointed nucleus	2 whorl large mammillate nucleus
13-14 axial ribs on body whorl	10-18 axial ribs on body whorl
colored bands	essentially uncolored
10 spiral grooves	7-8 spiral grooves with smaller ones between
heavy calloused toothed lip	thin lirate lip
slightly angular profile	rounded profile
ribs often prominent on body whorl	ribs usually evanescent on body whorl
	grows twice as large and has a proportionately longer canal.



FIGS. 3 and 6. **3,** *F. lightbourni*, paratype, 66 mm, DMNH 154462; protoconch and early whorls. **6,** *F. frenguellii*, 129 mm, by fishermen in 27 fms, sand and mud bottom, off Rio de Janeiro, Brazil, August 1975, author's collection; protoconch and early whorls.

Discussion: Fusinus lightbourni seems most closely related to *F. frenguellii* (Carcelles, 1953) (Fig. 4-6). The most obvious differences are its smaller adult size, the pale brown bands of coloration, and the details of its body sculpture. The comparison is facilitated with the aid of a table.

In the same collecting hauls, we identified a fair number of *Fusinus ceramidus* (Dall, 1889) previously known from Barbados. These are completely typical specimens of *F. ceramidus*, although a bit smaller than usual (28-32 mm). This represents a significant range extension for this taxon.

Acknowledgements

Mr. Jack R. H. Lightbourn of Bermuda donated all of the type material as well as various other specimens in the Delaware Museum of Natural History and the author's collection. The author had an enjoyable and helpful discussion regarding these shells with Russell Jensen of the Delaware Museum of Natural History. The photographs were furnished by Mr. Hal Lewis of Philadelphia, Pa. The author extends his appreciation to each of these individuals.

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NEWS

William J. Clench is recovering from an operation undergone in Boston in October. He is now in California with his son who is attending to his correspondence. Bill would welcome news from his friends and used postage stamps which he enjoys collecting. Write c/o Carleton W. Clench, 25431 Classic Drive, Mission Viejo, CA 92691.

Margaret C. Tesky, former Secretary of the A.M.U., after a serious fall has been hospitalized in North Carolina, and may be reached through William Dobo, P.O. Box 424, Wrightsville Beach, N.C. 28480.

A NEW WESTERN ATLANTIC SPECIES OF CYMATIUM (GASTROPODA: CYMATIIDAE)

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ABSTRACT

Cymatium raderi, *a new species from the east coast of Honduras, Central America, and the West Indies, is described and comparison is made with* C. femorale *(Linné, 1758) and* C. praefemorale *(Maury, 1917).*

Cymatium femorale (Linné, 1758) was very briefly described in the 10th edition of the *Systema Naturae*, p. 749, and this description was repeated almost verbatim in the 12th edition in 1767, p. 1217. To supplement this two-line description, Linné referred to several figures in the books of his time. However, three of the figures he referred to – namely, Rumphius (1711), t. 26, fig. B; Argenville (1742), t. 13, fig. B; and Regenfuss (1758), t. 2, fig. 21 – appear to be referable to *Cymatium lotorium* (Linné, 1758). Linné corrected this error in his manuscript notes (Dodge, 1957). Linné's remaining four references correctly figure *C. femorale:* Grew (1681), t. 11 (should be t. 10, figs 7, 8, wrongly figured as a sinistral specimen); Buonanni (1681), 3, t. 290. Linné in a manuscript note designated the figure in Buonanni as "bene" (Dodge, 1957) (See our fig. 1); Lister, t. 941; and Gualtieri (1742), t. 50, fig. C. Linné (1767) added to the synonymy Seba (1758), t. 63, figs. 7, 8 and these two figures are excellent (See our fig. 2). Figs. 9, 10 on t. 63 of Seba appear to be juvenile *C. femorale. Lotorium lotor* Montfort, 1810, is a junior synonym of *Cymatium femorale* Linné, 1758). Although Montfort referred to *Murex lotorium* Linné, 1758, Montfort's figure is *Cymatium femorale* (Linné, 1758).

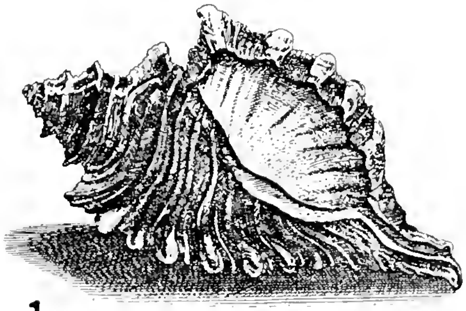

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FIG. 1. *Cymatium femorale* (Linné, 1758), taken from Buonanni (1681).

2

FIG. 2. *Cymatium femorale* (Linné, 1758), taken from Seba (1758).

The type of *C. femorale* is in the Linnean collection in London and conforms with the description and with the citations by Linné with the exceptions, as above stated, of Rumphius, Argenville and Regenfuss (Dodge, 1957). In his description Linné states "apertura edentula",

FIG. 3. *Cymatium femorale* (Linné, 1758), SDNHM 15664. Photograph by D. Gottleib.

FIG. 4. *Cymatium femorale* (Linné, 1758), SDNHM 15664. Photograph by D. Mulliner.

i.e. aperture without denticles. None of the figures referred to by Linné showed any denticles within the aperture. Figs. 3, 4 illustrate *C. femorale* (SDNHM 15664).

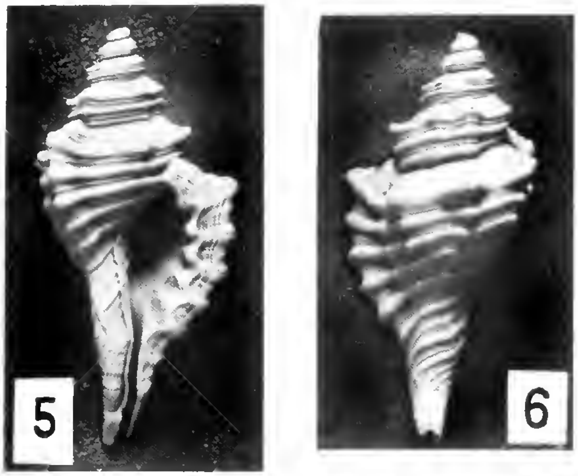
Clench and Turner (1957) placed *Septa triangularis* Perry, 1811, pl. 14, in the synonymy of *Cymatium femorale*, but the cited figure in Perry (1811) from the Southern Ocean appears to be a composite drawing of *C. lotorium* Linné, 1758, *C. femorale* Linné, 1758 and *C. perryi* Emerson and Old, 1963. For further discussion see Emerson and Old (1963).

Cymatium praefemorale (Maury, 1917) was described from a Tertiary fossil found at Rio Gurabo, Santo Domingo, West Indies. Figs. 5, 6 illustrate *C. praefemorale* (TU 1280).

L. J. Bibbey of San Diego, California, recently brought to our attention specimens of a *Cymatium* collected by fishermen in the Caribbean Sea off the east coast of Honduras, Central America, which bear a superficial resemblance to *C. femorale*. This new species has very obvious dentition within the aperture and in that respect resembles *C. praefemorale* (Maury, 1917). In the monograph by Clench and Turner (1957) on Cymatiidae, pl. 129, fig. 1, labelled *C. femorale* from Great Abaco, Bahama Islands, the figure appears to be a specimen of the new species and not *C. femorale* as described by Linné. Four lots are in the collection of the American Museum of Natural History. #182782, one specimen, (paratype) from Tobago Island, West Indies, collected by Sol Weiss of New York City. #205836 from Punta Potuca, Honduras, trawled from 18 to 27 m, one specimen, sent to the Museum by Helio Garcia. #107868, one specimen, from Dry Tortugas, Florida, collected by shrimpers, 1963. #205350, three specimens, from off Honduras, by fishermen, obtained from Jack Rader, via R. T. Abbott.

Differences in the general shape, rounding of the varices, less rugose sculpture and strong dentition distinguish this new species from both *C. femorale* and *C. praefemorale*.

Institutional Abbreviations: SDNHM (San



FIGS. 5, 6. *Cymatium praefemorale* (Maury, 1917) TU 1280. Photographs by A. Beu.

Diego Natural History Museum); AMNH (American Museum of Natural History); TU (Tulane University).

Family: *Cymatiidae* Iredale, 1913
Genus: *Cymatium* Röding, 1798

FIG. 7. *Cymatium raderi* n. sp., holotype, SDNHM 81627. Photograph by D. Gottleib.

FIG. 8. *Cymatium raderi* n. sp., holotype, SDNHM 81627. Photograph by D. Mulliner.

Type Species: Murex femorale Linné, 1758, by subsequent designation, Dall 1904, p. 133

Cymatium raderi *new* species
Figs. 7-12

Description: Length 152 mm by 88 mm wide; moderately strong with seven convex postnuclear whorls; suture distinct except where interrupted by the varices; protoconch eroded; first postnuclear whorl rounded; weak axial ribs begin on the second postnuclear whorl (12 per whorl are apparent up to the first varix which is on the fourth postnuclear whorl); spiral cords six on the first postnuclear whorl, increasing in number for each succeeding whorl; two of the spiral cords are stronger, one at the shoulder and one below the shoulder beginning on the third postnuclear whorl, increasing in strength on the fourth and fifth whorl and increasing to five in number on the body whorl; the cord on the shoulder gives a weakly angulate appear-

ance to the otherwise rounded whorls. One major cord and two to three weaker cords are present on the canal. The major cords and the remaining surface of the body whorl are covered with spiral threads. The shoulder contains only minor cords and spiral threads. Aperture elongate, oval, truncate posteriorly; canal open, tapering and recurved at termination. Inner lip strongly concave, very thin and adherent above; below the midpoint of the aperture the inner lip is slightly erect, with a dull pale-purple stain extending into the canal. Outer lip with four denticles, one within the truncate portion of the aperture. The remaining three denticles occur on the apertural side of the depressions between the spiral cords on the posterior portion of the aperture; the most anterior denticle is bifid. These denticles begin well away from the lip edge. The outer lip reflects the undulating character of the spiral sculpture; deep brownish purple coloring occurs in the depressions between the spiral cords within the aperture. Inside of aperture white. Ventral side of the expanded apertural varix is concave at the peristome and strongly stained with deep-brown between the six white spiral cords and extending to the rounded edge of the varix. These cords are white only on the ventral surface of the leading side of the varix. The shell has five rounded varices, the first on the fourth postnuclear whorl, the second on the body whorl opposite the one on the apertural side. The varices terminate posteriorly in a convex sloping plane from the suture. Axial sculpture consists of three nodes on the shoulder of the body whorl, the center node projecting most prominently, nodes very weakly developed or lacking on the cords below.

Color: Externally, the color is a warm reddish ochre, becoming richest on the receding side of the apertural varix.

Type Material: Holotype, 185 mm×90 mm (SDNHM 81627); Paratype A, 136 mm×59 mm (SDMNH 81628); Paratype B, 187 mm×87mm (AMNH 182782); L. J. Bibbey collection – Paratype C, 196 mm×87 mm; Jack Rader collection – Paratype D, 192 mm×87 mm; Jack Rader collection – Paratype E, 124 mm×69 mm.

FIGS. 9, 10. *Cymatium raderi* n. sp., paratype C, Bibbey collection. Photographs by D. Gottleib

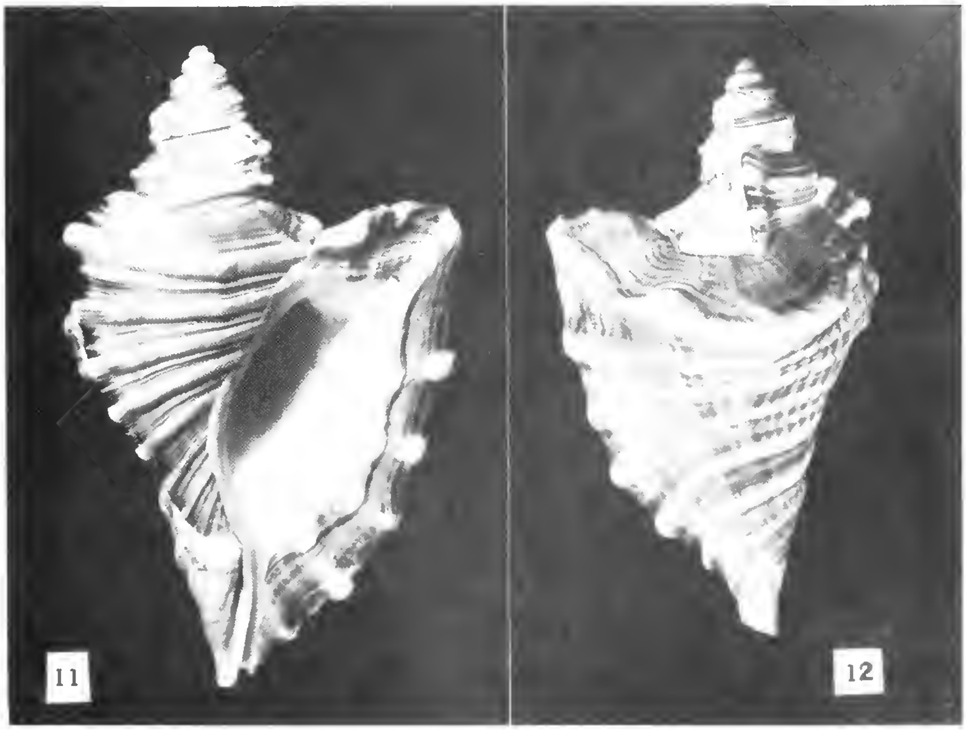
Type Locality: Collected by fishermen off the east coast of Honduras, Central America, Caribbean Sea. An additional specimen was discovered in the American Museum of Natural History no. 182782 from Tobago Island, West Indies.

Etymology: Named for the late Jack Rader, who first recognized the differences in this new species.

Discussion: Paratype C, figs. 9, 10 from the Bibbey collection is a slender, elongate specimen, light in weight, with an immature lip. Paratype D. figs, 11, 12, from the Rader collection has an extreme development of the central shoulder node changing into a broad tabulate projecting shelf. The apertural varix is also more extensively developed, and the shell is strong and heavy, with weak, bifid denticles within the aperture.

Comparison of the new species with *Cymatium femorale* shows differences in the shape and sculpture. *Cymatium raderi* does not have the more clearly defined trigonal shape of *C. femorale,* and the varices are rounded rather than pointed at the shoulder. The extension of the varix in *C. femorale* rises spinelike into a projection and slopes concavely to the suture. In comparison the varix of the new species is truncate most posteriorly and slopes convexly and anteriorly from the suture. The sculpture of *C. raderi* is much less rugose, the spiral cords are broad and rounded between moderate to weak depressions, and the intervarical areas are without prominent nodes. The spiral cords of *C. femorale* are raised between deep depressions to a greater degree than in *C. raderi;* this is especially emphasized on the varices where the stronger and heavier cords project into prominent nodes. These nodes are white, both on the leading edge and also on the receding edge of the varices. *C. raderi* has less prominent nodes that are white only on the leading edge of the varices. The shoulders of the whorls in *C. femorale* are angulate and they appear tabulate, while in *C. raderi* they are very weakly angulate. A prominent feature of *C. femorale* is the axially oriented nodes on the spiral cords which in *C. raderi* are weak to absent. There are no nodes or denticles within the aperture of *C. femorale,* while the aperture of *C. raderi* is strongly dentate.

Comparison of the new species with *C. praefe-*



FIGS. 11, 12. *Cymatium raderi* n. sp., paratype D, Rader collection. Photographs by D. Gottleib.

morale shows differences in the following characters: *C. praefemorale* has stronger cords and costae than *C. raderi*. Two to four rows of prominent axially oriented nodes similar to those in *C. femorale* appear on the body whorl between the varices. Within the aperture of *C. praefemorale* there are six strong swollen denticles (none of these are bifid as in the new species), beginning at the margin of the outer lip and extending well into the aperture. All denticles are of approximate equal size and extend from the anal trough anteriorly to the siphonal canal. *Cymatium praefemorale* also has numerous plicae that extend along the columella whereas *C. raderi* has only one or two plicae on the anterior portion of the columella. The entire surface of the seven specimens of *C. praefemorale* examined have easily visible raised axial striae. This character is decidedly more weakly developed in both *C. femorale* and the new species.

C. praefemorale further differs from the new species by its much smaller size (ranging from 61 mm to 92 mm), the stronger more numerous plicae on the columella and the ridged appearance of the surface due to the strong development of the growth striae.

In summary, the new species may be most readily distinguished by the following characters: the truncate downward-sloping termination of the varices, the dentate aperture, the weaker spiral cords and the lack of prominent intervarical axial nodes present on most specimens of *C. femorale* and *C. praefemorale*.

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NOTES ON THE MORPHOLOGY OF *OLSSONELLA SMITHII* (GASTROPODA: CANCELLARIIDAE)[1]

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ABSTRACT

Olssonella smithii *(Dall, 1888) is a small cancellariid gastropod that inhabits sand substrates off the southeastern United States, the Gulf of Mexico, Colombia and Venezuela. It resembles* Cancellaria reticulata *(Linné, 1767) in anatomical organization, but differs in having a less specialized anterior alimentary system and an unmodified left cephalic tentacle. Shell ultrastructure is similar in these two species, although* O. smithii *has a thicker periostracum.* Olssonella smithii *also lacks bifurcated columellar folds and has internal varices that differ in periodicity from those of* C. reticulata. *Based on the morphology of radulae and jaws we suggest that the subfamilies Cancellariinae and Trigonostominae are more closely related to each other than either is to Admetinae, in which there is a trend toward loss of the radula.*

The Cancellariacea comprise a highly specialized, poorly known and taxonomically enigmatic group of marine gastropods. Although they form a morphologically compact natural assemblage, their relationships to other prosobranchs are less than certain. The group has been included in the Toxoglossa by early workers (eg. Troschel, 1865; Tryon, 1882; Fischer, 1883), in the Volutacea (eg. Thiele, 1929; Wenz, 1938-1944; Taylor and Sohl, 1962) and elevated to ordinal status by Olsson (1970) who proposed the name Nematoglossa. Golikov and Starobogatov (1975) reduced the group to a suborder, but retained the name Nematoglossa. Most recent workers regard this group as a superfamily within Neogastropoda (Ponder, 1973; Keen and Coan, 1974; Taylor *et al.*, 1980; Boss, 1982). Taylor *et al.* (1980) suggest that Cancellariacea are derived from the Purpurinidae (Middle Triassic-Upper Cretaceous), which they resemble in shell morphology.

Various higher level classifications based exclusively on shell characters have been proposed (see Marks, 1949, for a review of the early work), but phylogenetic relationships have yet to be investigated.

Anatomical studies have, for the most part, been limited to radular morphology (eg. Troschel, 1865; Barnard, 1958; Olsson, 1970; Oliver, 1982; Schremp and Richmond, 1983; Schremp, 1983) or to the anterior alimentary system (Amaudrut, 1898; Graham, 1966). The gross anatomy of *Cancellaria reticulata* (Linné, 1767) has recently been described (Harasewych and Petit, 1982).

We recently obtained several preserved specimens of *Olssonella smithii* (Dall, 1888), a species taxonomically remote from *Cancellaria reticulata*, and examined its shell and soft parts in order to investigate the morphological diversity within Cancellariacea.

There are few literature citations for *Olssonella smithii.* This species was originally described from off Cape Hatteras, North Carolina, a record which probably represents its most northern range. Specimens were reported from the northwestern Campeche Bank, Yucatan Peninsula, Mexico (Rice and Kornicker, 1965) and from the coasts of Colombia and Venezuela [Petuch, 1981, as *Agatrix epomis* (Woodring)]. Other Venezuelan specimens ten-

[1]Contribution no. 127, Smithsonian Marine Station, Link Port, Florida.

tatively identified as *O. smithii* were reported by Princz (1982).

Several authors have placed *Olssonella* as a subgenus of *Agatrix*, an assignment we do not accept as we feel that the two genera are separable and there is no evidence for a subgeneric relationship.

Materials and Methods

The following specimens were used in this study:

1 ♀, trawled in 110-99 meters, E. of Sebastian Inlet, Florida (27°48′N,79°55′W) on *Oculina* bed (Indian River Coastal Zone Museum 65:585).

1 ♀, dredged in 45.7 meters, about 28 nautical miles NE of Cape Canaveral, Florida (28°44′N, 80°10′W) R/V Delaware II, Cruise 824, sta. 90. (Voucher specimen-National Museum of Natural History, Smithsonian Institution 806986).

1 ♂ and 2 ♀, dredged in 80.4-84.1 meters, about 78 nautical miles E of Savannah River Mouth, Georgia (32°02′N,79°18′W) R/V Delaware II, Cruise 824, sta. 16.

1 ♂ and 1 ♀, dredged in 45.7-47.5 meters, about 24 nautical miles NE of Cape Canaveral, Florida (28°39′N,80°09′W) R/V Delaware II, Cruise 824, sta. 91.

Specimens for anatomical and histological studies were immersed in 10% hydrochloric acid (HC1) until the shells dissolved. Soft parts were rinsed in distilled water and returned to 70% ethanol for dissection. One male and one female specimen were sectioned at a thickness of 8 μm and the sections stained in hematoxylin and eosin. Dry shells were sectioned with a diamond saw or fractured in a vise for examination of internal structure and ultrastructure.

Shell Morphology

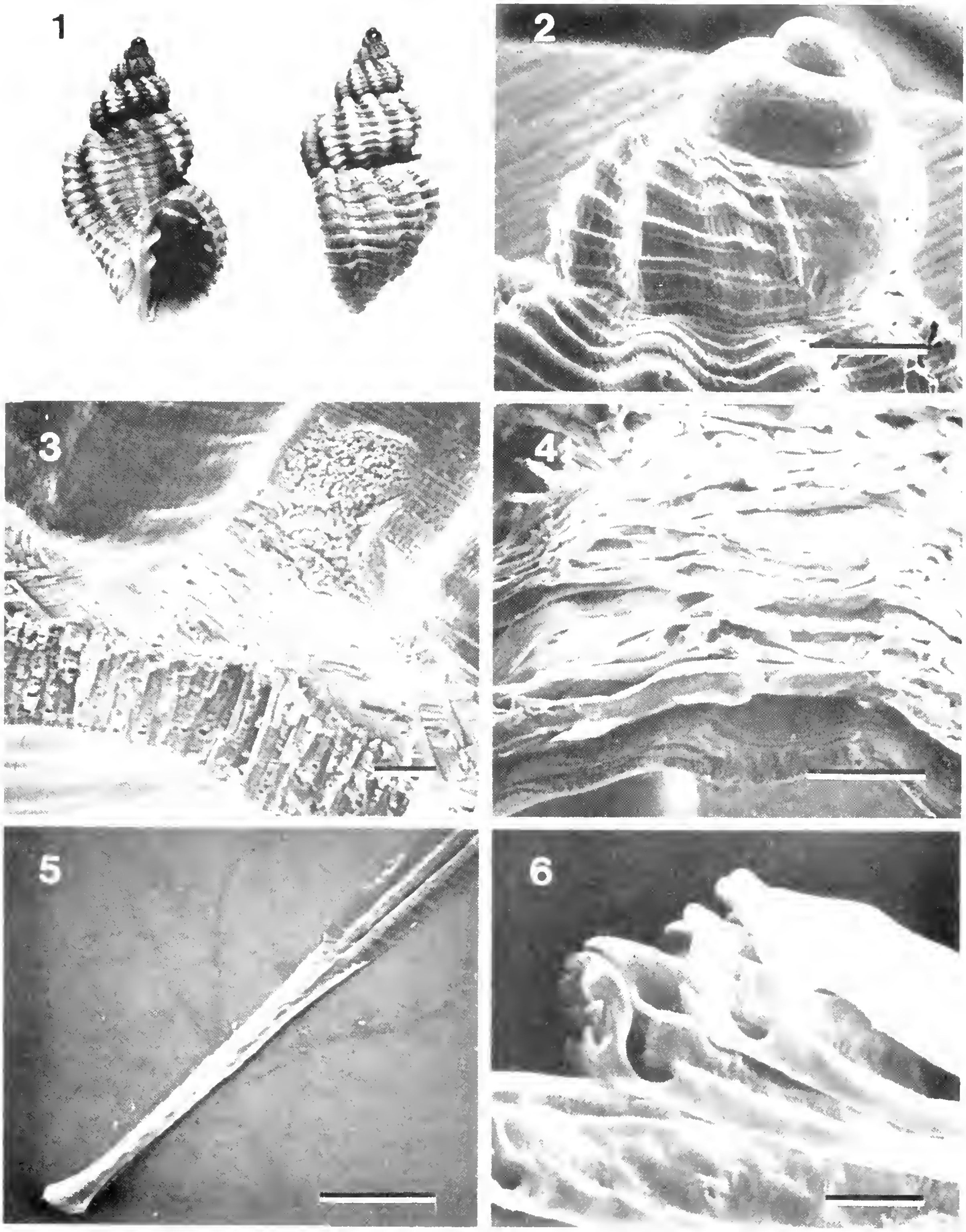
External: Shell small (to 15 mm), heavy, elongate-oval, with conical spire and rounded anterior (Fig. 1). Protoconch deviated by 10-15°, consisting of about 2 dark-brown, inflated glassy whorls. Transition to teleoconch marked by abrupt acquisition of spiral sculpture (Fig. 2). Teleoconch with up to 4⅔ strongly convex whorls. Suture deeply impressed. Spiral sculpture of 15-19 cords on body whorl and 8 or 9 on penultimate whorl, with or without one fine striae between. Collabral sculpture of 8-11 strong, evenly-spaced, prosocline ribs per whorl. There is a slight increase in number of spiral cords and a decrease in number of axial ribs with increase in shell size. Aperture hemielliptical, deflected from coiling axis by 10-15°. A shallow indentation separates the very abbreviated siphonal canal from the outer lip, which contains 8 or 9 spiral lirae that are thickest beneath axial ribs. Inner lip with 2 simple columellar folds and a siphonal fold. Anterior half of inner lip forms a raised inductura beneath which the pseudoumbilicus appears as a narrow fissure. Color creamy tan to purplish brown, lightest on axial ribs, darker between, and darkest along suture. Some specimens have a white band across the middle of the body whorl. Aperture white to purplish brown, columellar folds and apertural lirae white.

TABLE 1. *Olssonella smithii* (Dall), measurements of shell characters (in mm) n = 10.

Character	mean	range	standard deviation
Shell length	10.86	6.8-14.9	3.29
Shell width	6.38	4.2-8.7	1.79
Aperture length	5.08	3.3-6.6	1.24
$\frac{\text{Aperture length}}{\text{Shell length}}$	0.477	0.438-0.542	0.042
# whorls, protoconch	1.76	1.7-2.0	0.09
# whorls, teleoconch	3.71	3.0-4.7	0.67
# ribs on final whorl	9.1	8-11	0.99
Spire angle	55.9°	53-59°	1.9°

Internal: Sectioned and fractured shells reveal that internal surfaces are smooth and continuous in the early whorls. By the third post-nuclear whorl, apertural lirae develop and columellar folds increase in prominence. Apertural lirae span 3 axial ribs then become reduced or absent for 3 axial ribs before again enlarging and spanning 3 ribs (periodicity roughly 240°). Unlike *C. reticulata*, the location of the apertural lirae is not discernible on the outer surface of the shell. Columellar folds become pronounced every 120°, with every other columellar prominence occurring in opposition to the median of the 3 lirate axial ribs.

Ultrastructure: A thick, yellowish, lamellose periostracum (Fig. 4) overlies the shell, which consists of 2 orthogonal layers of crossed-lamellar aragonite (Fig. 3). The outer layer, in which the lamellar planes are collabral, varies in thickness from 400-800 μm and comprises the

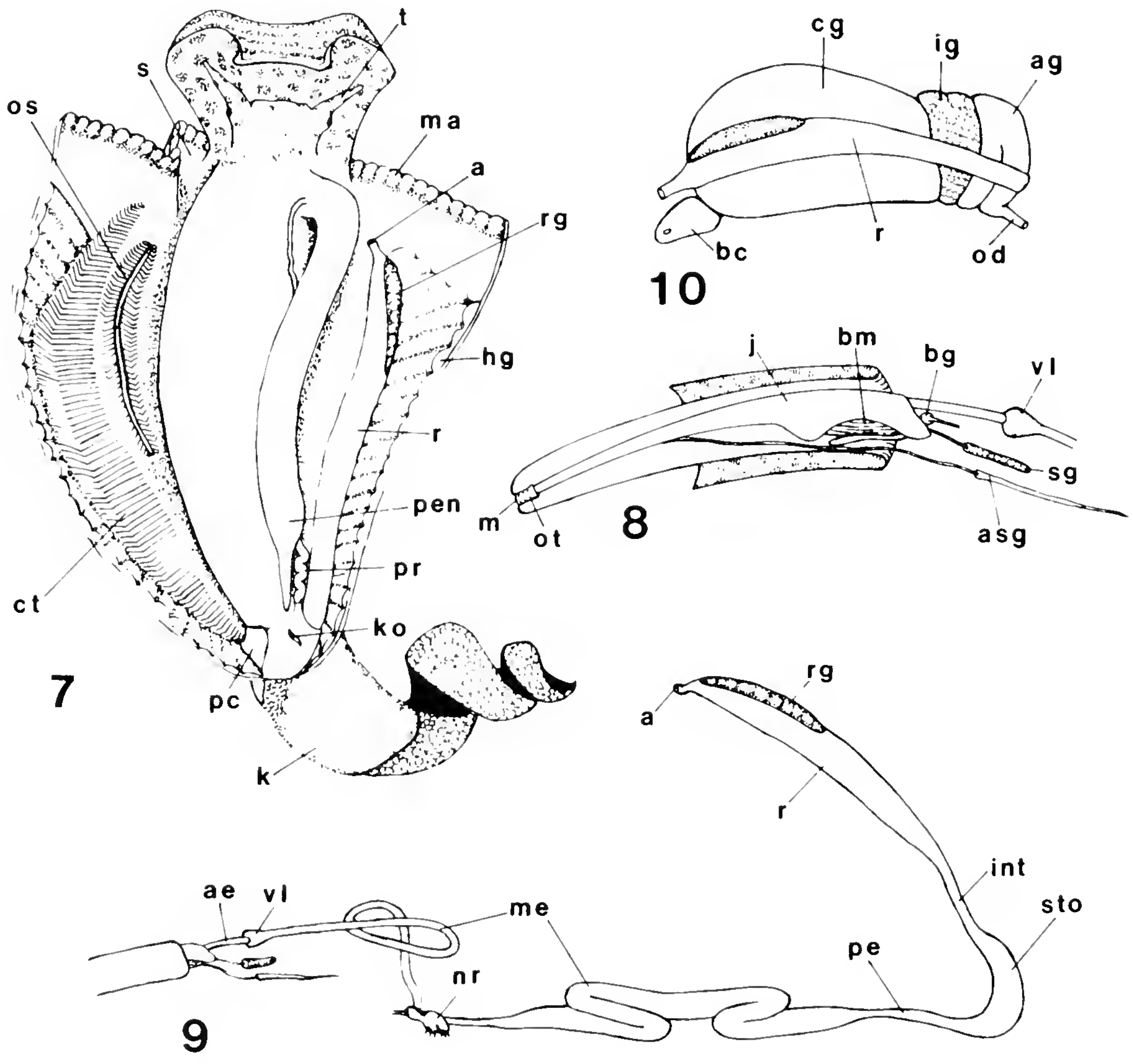


FIGS. 1-6. Shell and radular features of *Olssonella smithii* (Dall). **1**, Apertural and right side views of a female specimen dredged in 45.7 meters, about 28 nautical miles NE of Cape Canaveral, Florida. (USNM 806986). 4×. **2**, Protoconch. Scale bar = 400 μm. **3**, Fracture surface. Plane of fracture parallel to outer lip. Scale bar = 50 μm. **4**, Periostracum. Scale bar = 200 μm. **5**, Proximal end of radular tooth, detached from radular ribbon. Scale bar = 10 μm. **6**, Side view of distal ends of radular teeth. Scale bar = 3 μm.

axial ribs, spiral cords and internal lirae. The inner layer, with transversely oriented lamellar planes, forms a fairly uniform lining (100-150 μm) along the inner surface of the shell.

Soft Parts Morphology

External features: The shell-less animal consists of approximately 3½ whorls, with the digestive gland comprising 2 whorls, the kidney ¼ whorl and the mantle cavity extending over ⅔ whorl. Preserved animals were retracted to just within the final set of apertural lirae. Animals were light tan in color, with reddish brown spots that covered the upper and lateral surfaces of the short, rectangular foot and the symmetrical tentacles (Fig. 7, **t**), but stopped just within the strongly papillose mantle edge (Fig. 7, **ma**). The siphon (Fig. 7, s) is short and blunt. The opercu-



FIGS. 7-10. Anatomical features of *Olssonella smithii* (Dall). **7**, Male specimen removed from shell, partially uncoiled and mantle cavity opened mid-dorsally to display contents. **8**, Dissection of retracted proboscis, viewed from left side. **9**, Diagrammatic representation of the alimentary system. **10**, Diagrammatic representation of the female pallial gonoduct. **a**, anus; **ae**, anterior esophagus; **ag**, albumen gland; **asg**, accessory salivary gland; **bc**, bursa copulatrix; **bg**, buccal ganglion; **bm**, buccal mass; **cg**, capsule gland; **ct**, ctenidium; **hg**, hypobranchial gland; **ig**, ingesting gland; **int**, intestine; **j**, jaw; **k**, kidney; **ko**, kidney opening; **m**, mouth; **ma**, mantle edge; **me**, mid-esophagus; **nr**, nerve ring; **od**, oviduct; **os**, osphradium; **ot**, oral tube; **pc**, pericardium; **pe**, posterior esophagus; **pen**, penis, **pr**, prostate, **r**, rectum, **rg**, anal gland; **sto**, stomach; **t**, tentacle; **vl**, valve of Leiblein.

lum is lacking.

Mantle cavity: The arrangement of organs within the mantle cavity is similar to that of other higher prosobranchs. The osphradium (Fig. 7, **os**) (L/W ≅ 3) consists of 35 leaflets per side. Immediately adjacent is the ctenidium (Fig. 7, **ct**), slightly wider and twice as long as the osphradium and composed of about 115 triangular leaflets. Occupying the roof of the mantle cavity is the voluminous, whitish, transversely pleated hypobranchial gland (Fig. 7, **hg**). To its right lie the rectum (Fig. 7, **r**) and genital ducts. The kidney (Fig. 7, **k**) lines the rear of the mantle cavity and opens into it by a single vertical slit (Fig. 7, **ko**). The pericardium (Fig. 7, **pc**) is embedded in the left side of the kidney, with only a small area bordering the mantle cavity.

Alimentary system: The stout, tubular, pleurombolic proboscis, which can be extended nearly the length of the shell, is the same color as the foot (i.e. tan with reddish brown spots on the dorsal and lateral surfaces). When the proboscis is retracted, the large buccal mass (Fig. 8, **bm**) extends beyond its posterior limits. A short oral tube (Fig. 8, **ot**) leads from the mouth (Fig. 8, **m**) to the cuticularized, tube-like jaw (Fig. 8, **j**), the expanded posterior portion of which surrounds the buccal mass. The dorsal surface of the buccal mass is covered by a broad, medially-grooved cuticle that supports a radular ribbon consisting of a single row of 54-56 ($n=4$) long ($\sim$900 μm), narrow ($\sim$20 μm at base) teeth. Each tooth appears to consist of a recurved ribbon 30 μm wide (Fig. 5), the distal end of which has 3 highly modified cusps: the 2 lateral, inwardly directed cusps each have a complex of secondary cusps (Fig. 6). Two pairs of salivary glands lie behind the buccal mass. The larger pair (Fig. 8, **sg**) are tubular, their ducts entering the buccal mass anterior to the esophageal opening. A second longer but narrower pair of glands (Fig. 8, **asg**) empty via ducts into the oral tube. The short anterior esophagus (Fig. 9, **ae**) runs from the roof of the buccal cavity to a large, muscular valve of Leiblein (Figs. 8, 9, **vl**). Posterior to this valve lies the mid-esophagus (Fig. 9, **me**), which becomes convoluted before passing through the nerve ring (Fig. 9, **nr**) and winding posteriorly along the floor of the cephalic sinus. There is no gland of Leiblein, but a narrow glandular strip lines the dorsal surface of a portion of the mid-esophagus. The straight, narrow posterior esophagus (Fig. 9, **pe**) begins at the rear of the cephalic sinus and leads to a simple, U-shaped stomach (Fig. 9, **sto**). Longitudinal folds run through the stomach and into the intestine (Fig. 9, **int**), which passes through the kidney and continues along the right side of the mantle cavity where it expands to form a rectum (Figs, 7, 9, 10, **r**). A small anal gland (Figs. 7, 9, **rg**) runs along the dorsal anterior portion of the rectum to a point where it detaches from the roof of the mantle cavity to form the anus (Figs. 7, 9, **a**). No identifiable gut contents were found in any of the specimens examined.

Female reproductive system: The female reproductive system is similar in most respects to that of *Cancellaria reticulata* (Harasewych and Petit, 1982). The yellowish, ascinous ovary lies at the posterior-most portion of the visceral mass. From it a thin-walled oviduct (Fig. 10, **od**) runs anteriorly along the columellar side of the digestive gland, kidney and pericardium before entering the rear of the mantle cavity. No gonopericardial duct was found. The pallial portion of the oviduct consists of an albumen gland (Fig. 10, **ag**), a small, tubuliferous ingesting gland (Fig. 10, **ig**), a large, ovate capsule gland (Fig. 10, **cg**) and a triangular bursa copulatrix (Fig. 10, **bc**).

Male reproductive system: The male reproductive system does not differ markedly from that of *Cancellaria reticulata* (Harasewych and Petit, 1982). The testis lines the columellar side of the digestive gland and gives rise to a testicular duct that runs anteriorly along the visceral mass, becoming convoluted when adjacent to the kidney, then straightening and entering the rear of the mantle cavity. Here it expands, becoming convoluted and glandular (Fig. 7, **pr**), then constricts again and leads to the base of a long, cylindrical penis (Fig. 7, **pen**). The penis, ovate in cross-section, contains a coiled penial duct and has a terminal papilla.

Nervous system: As in *Cancellaria reticulata* (Harasewych and Petit, 1982), the nervous system is highly concentrated with the cerebral, pleural, pedal and subesophageal ganglia fused into a nerve ring (Fig. 9, **nr**) that encircles the esophagus and anterior aorta. The buccal ganglia are at the rear of the buccal mass, but neither the proboscis nor the cerebro-buccal

connectives are as long as in *C. reticulata.*

Discussion

Within the cancellariacean framework, *Olssonella smithii* is less specialized than is *Cancellaria reticulata* both in shell structure and in anatomical organization. Table 2 lists major anatomical differences between these two species, with asterisks denoting conditions we consider to be derived.

The diet of cancellariids remains a mystery, as no identifiable gut contents could be found in any species examined. However, the highly modified chemoreceptive organs and anterior alimentary system of *C. reticulata* suggest a more specialized diet for that species. *Olssonella smithii* has a simpler anterior alimentary system, but the very large hypobranchial gland suggests the possibility of toxin production (Halstead, 1965).

Olssonella smithii is also less specialized in shell architecture, lacking the external evidence of internal varices and bifurcated columellar folds of *C. reticulata.* The former species has apertural lirae every 240° rather than every 120° as found in the latter. Shell ultrastructure is similar in both species, although *O. smithii* has a thicker, coarser periostracum.

Attempts to investigate morphological diversity within the Cancellariacea have been hampered by a lack of a phylogenetic arrangement of the approximately 100 nominal supraspecific taxa within the group. The superfamily has been divided into the Cancellariidae and the extinct Paladmetidae (Sohl, 1964; Ponder, 1973). Cancellariid genera have, in general, been clustered around three morphological types that have been elevated to the subfamilies Cancellariinae, Trigonostominae and Admetinae (Cossmann, 1899).

Cancellaria reticulata, whose anatomy has recently been described (Harasewych and Petit, 1982), is the type species of *Cancellaria* Lamarck, 1799. *Olssonella smithii,* the type species of *Olssonella* Petit, 1970, may serve as exemplar of the Trigonostominae. No general anatomical studies of any species of Admetinae are known to us, although a brief description of a living *Admete viridula* (Fabricius, 1780) is given by Jeffreys (1876) and repeated by Tryon (1885). Thiele (1929), Powell (1951) and Oliver (1982) have published figures or descriptions of radulae and jaws of members of this subfamily. The limited data available show that Cancellariinae and Trigonostominae are more closely related to each other than either is to Admetinae. Representatives of the first two "subfamilies" have radular teeth in which the outer cusps have secondary cusps; indeed, the principle radular differences seem to lie in the patterns of this secondary dentition. In contrast, the outer "cusps" of admetine radular teeth are bulbous

TABLE 2. Anatomical differences between *Olssonella smithii* and *Cancellaria reticulata.* Asterisk denotes derived condition.

Character	*Olssonella smithii*	*Cancellaria reticulata*
Left cephalic tentacle	normal	*bilobed
distance between osphradium and ctenidium	normal	*enlarged
hypobranchial gland	*hypertrophied	normal
proboscis shape	tubular, smooth	*ventrally flat, papillose
proboscis	normal, pleurombolic	*posterior portion of retracted proboscis serves as proboscis sheath
buccal mass	large, protrudes posteriorly when proboscis is retracted	*small, contained in anterior portion of proboscis
valve of Leiblein	large, normal	*reduced to bulge on esophagus
middle esophagus	*?expanded	narrow
penis	cylindrical	*?flat
bursa copulatrix	triangular	*?rectangular
cerebro-buccal connective	*long	**very long

and nearly hemispherical, with the central portion of the tooth lined with longitudinally arranged barbs (Oliver, 1982: Figs. 3, 5). Within Admetinae the jaw is shorter (Oliver, 1982: Fig. 4), lacking the posterior lobes present in jaws of Cancellariinae (Olsson, 1970: Fig. 13) and Trigonostominae (Olsson, 1970: Fig. 24).

Admete magellanica (Strebel, 1905) lacks a radula but has a tubular jaw (Oliver, 1982:16) suggesting to us a trend toward loss of radula in Admetinae with the tubular jaw being used as a piercing stylet, as in the pyramidellids.

Admittedly, these interpretations are speculative, being based on minimal data. It is hoped further work will shed more light on some of the hypotheses proposed.

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COMPARISON OF THE DIETS OF THE TIDAL MARSH SNAIL, *MELAMPUS BIDENTATUS* AND THE AMPHIPOD, *ORCHESTIA GRILLUS*

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ABSTRACT

The diet of the opportunistically-feeding snail, Melampus bidentatus *Say is essentially the same as that of the amphipod,* Orchestia grillus *(Bosc). These animals are co-inhabitants in the high marsh regions of the Pataguanset Tidal Marsh in Niantic, Connecticut. In addition to gut content analyses of both species, criteria for identifying microscopic samples of the most abundant plant material, including the animals' main food,* Spartina patens, *were established. Because of the abundance of available food items, competition between the two species appears to be minimal.*

In spite of the fact that *Melampus bidentatus* appears in large numbers in the tidal marshes along the east coast of North America, few studies, either qualitative or quantitative, have been made on their food preferences or dietary habits. Although Hausman (1936) reported on the chief components of the *Melampus* diet, her study did not list the number of animals analyzed nor the methods of data compilation. Thus only limited conclusions can be drawn from this previous literature.

The current study consisted of 1) a survey of the plant material available on the marsh with compilation of criteria for identifying small plants and fragments of larger plants under a microscope to facilitate gut content analysis; 2) the analyses of the gut and feces contents of both *M. bidentatus* and *O. grillus* in order to determine the major seasonal components of their diets; and 3) a follow-up examination of winter feeding activity of *M. bidentatus.*

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Study Site and Methods

The initial study was conducted on the tidal marshes of Watts Island in the Pataguanset Estuary west of Niantic Bay in Connecticut. This island, measuring 10 acres, has small areas of upland vegetation consisting mainly of oaks and poison ivy. The dominant vegetation, however, is *Spartina patens* which occurs in pure stands or mixed with *Distichlis spicata, Juncus gerardi* and *Spartina alterniflora.* The estuary surrounding the island, as well as the ditches traversing the marsh, are filled with *Ruppia maritima* and *Enteromorpha* spp. in the spring and summer. In the winter large amounts of loose algae, including *Ulva lactuca, Enteromorpha* spp. and *Ascophyllum nodosum,* wash onto the marsh surface along with decaying eelgrass (*Zostera marina*).

The algal mat, densely covering much of the marsh surface, consists largely of *Rhizoclonium riparium, Vaucheria* spp. and diatoms, with lesser quantities of the blue-green algae, *Lyngbya* spp. and *Oscillatoria* spp. Mixed into the

mat are small animals such as nematodes which inhabit this layer and large amounts of grass and animal detritus.

In order to determine changes in the plant material available to consumer species on Watts Island, seasonal surveys of the grasses, forbs and macroalgae were made as well as microscopic analyses of small sections of the algal mat which had been scraped from the marsh surface. The plants were collected from various sites on Watts Island and brought back to the laboratory for processing.

A series of photomicrographs of cuticular and epidermal fragments of 16 salt marsh grasses, forbs and algae, suspected of being possible food items for *M. bidentatus* and *O. grillus* was prepared and shows characteristic features specific to each species.

In preparing grass samples to be photographed, a handful of grass blades were cut into 2 cm lengths, placed in a Waring blender, covered with distilled water and processed for 15 seconds. The resulting mixture was then poured into a petri dish and examined under a dissecting microscope. Suitable epidermal fragments were removed with a pipette, mounted in a drop of aerosol and photographed at 100× magnification. Macroalgae samples were processed in much the same manner. Cuticle replicas were made of the leaf surfaces of forbs by applying clear nail lacquer to both abaxial and adaxial sides. After air drying the lacquer replica was peeled off with forceps, mounted in aerosol and photographed under low illumination. Photomicrographs were also made of microalgae scraped from the algal mat and sketches were made of the diatoms most commonly found on the marsh surface. These photomicrographs and sketches were then used for comparison in identifying fragments taken from the gut and fecal samples of *M. bidentatus* and *O. grillus.*

Snails and amphipods used for gut content analyses were collected seasonally from eight sites across Watts Island, preserved in 70 percent alcohol and transported back to the laboratory where they were measured and then dissected under a binocular microscope. During the winter, two groups of inactive snails were collected: one group was preserved immediately upon removal; the other was used as a control to determine if the inactive snails were alive. In a follow-up study two years later, maximum and minimum air temperatures, peat temperature and position of *Melampus* on the marsh were recorded biweekly from November through April at Cottrell Marsh. This tidal marsh is located in Mystic, Connecticut, about 25 km east of Niantic and has a vegetation pattern similar to that on Watts Island. Three times during this follow-up study snails were collected and preserved for future gut content analyses.

Stomach contents, usually in the form of a well-compacted amorphous mass, were removed and placed on a microscope slide in a drop of distilled water. The mass was broken up with a fine dissecting needle in order to separate fragments and then examined under 100× and 450× magnification. Food items present were listed according to species, and the percentage of the total gut content volume was visually estimated for each item. A tabulation was then made of percent frequency of consumption of each food item by dividing the number of animals containing a particular item by the total number of animals examined.

Live animals were also collected seasonally, rinsed in seawater and placed in a petri dish on filter paper soaked in seawater. Fecal samples were collected after 24 hours, mounted in distilled water and examined under the compound microscope.

Observations

Diagnostic microscopic features found on the abaxial and adaxial epidermal surfaces and leaf margins which were used in the identification of the tidal marsh grass, rush and forb species frequently found in the gut contents of *M. bidentatus* and *O. grillus* are summarized in Tables 1 and 2. Examples of some of these features are shown in Fig. 1.

In all seasons plant material, varying from 0.5 mm square fragments to single cells, epidermal hairs, diatoms, microalgae and cell inclusions such as chloroplasts, formed the bulk of material found in the gut and feces of both *M. bidentatus* and *O. grillus.* Although a large percentage of the filamentous algae was still fresh and intact, fresh grass particles or those still containing large amounts of chlorophyll were never found in any of the guts. In fact, live animals being held in the laboratory refused to eat fresh grass

TABLE 1. Microscopic features used in the identification of grass and rush species.

Species	Identifying Features
Spartina alterniflora	
Abaxial Epidermis	
	Long Cells – thin, sinuous walls.
	Short Cells – abundant, solitary.
	Stomata – numerous, in longitudinal rows.
Adaxial Epidermis	
	Cells – rectangular with thin, sinuous walls.
	Papillae – small; 2-3 rows per cell.
Spartina patens	
Abaxial Epidermis	
	Long Cells – thin, sinuous walls.
	Short Cells – abundant, solitary.
	Stomata – scattered.
Adaxial Epidermis	
	Cells – rectangular with thin, sinuous walls.
	Papillae – small; single row per cell.
Distichlis spicata	
Abaxial Epidermis	
	Long Cells – thin, sinuous walls over veins; between veins, shorter, broader, with coarse sinuations.
	Short Cells – abundant.
	Stomata – present but infrequent.
Adaxial Epidermis	
	Numerous pronounced ribs.
	Papillae – large, conical; densely cover entire surface.
Juncus gerardi	
Abaxial Epidermis	
	Long Cells – thin, sinuous walls.
	Short Cells – absent.
	Stomata – large, abundant.
Adaxial Epidermis	
	Large, rectangular cells with thin, sinuous walls.
Phragmites australis	
Abaxial Epidermis	
	Long Cells – thin, coarsely sinuated walls.
	Short Cells – solitary between veins; paired over veins.
	Prickle Hairs – between veins; hooked, resemble papillae.
Adaxial Epidermis	
	Not examined.

TABLE 2. Microscopic features used in the identification of seagrasses, forbs and algae.

Species	Identifying Features
Ruppia maritima	Rows of cuboidal cells.
Zostera marina	Cells mostly hexagonal, in rows.
Limonium carolinianum	Elongated cells with nonsinuous walls. Sunken stomata in longitudinal rows.
Salicornia europaea	Cells of varying and irregular shapes. Numerous, dispersed stomata.
Iva frutescens	Cells of varying and irregular shapes (smaller than *Salicornia*). Dispersed stomata.
Rhizoclonium riparium	Branching filaments. Uniserate arrangement of cells.
Enteromorpha spp.	Branching filaments. Multiserate arrangement of cells.
Polysiphonia harveyi (Bail)	Branching filaments. Four pericentral cells.
Ulva lactuca	Sheets of cells in mosaic-like arrangement.
Lyngbya spp.	Single trichome enclosed in a sheath.
Microcoleus spp.	Many trichomes enclosed in a single sheath.

particles but readily consumed filter paper. The percent frequencies of occurrence of particular food items found in the gut contents of 220 *M. bidentatus* and 81 *O. grillus* during the fall, winter, spring and summer of 1980 and 1981 are shown in Figs. 2 and 3.

Animal material, which most frequently included jointed insect appendages, occurred in 32% of the *Melampus* and 17% of the *Orchestia*. In some cases intact foraminiferans, mites, ostracods and nematodes were present.

Of the plant material, *S. patens* fragments were present in 51% of the *Melampus* examined and 42% of the *Orchestia*. *S. alterniflora* was present in 27% of the *Melampus* and 30% of the *Orchestia*. Of the other marsh grasses only *J. gerardi* was found in more than 10% of the animals. A small amount, 6% in *Orchestia* and 3% in *Melampus*, of eelgrass was found in the spring samples and in 12% of the fall *Melampus* specimens.

Rhizoclonium riparium was the most frequently found alga, occurring in 52% of the *Melampus* and 19% of the *Orchestia*. During the spring and summer an increased number of both snails and amphipods showed the presence of the blue-green algae, *Chrococcus* spp., *Lyngbya* spp. and *Oscillatoria* spp. as well as the yellow-green, *Vaucheria* spp. Frequency of diatom consumption was consistently high for *Melampus* at 69% but averaged only 22% for *Orchestia*. All food material was frequently mixed with sand.

In the initial winter study, snails were found

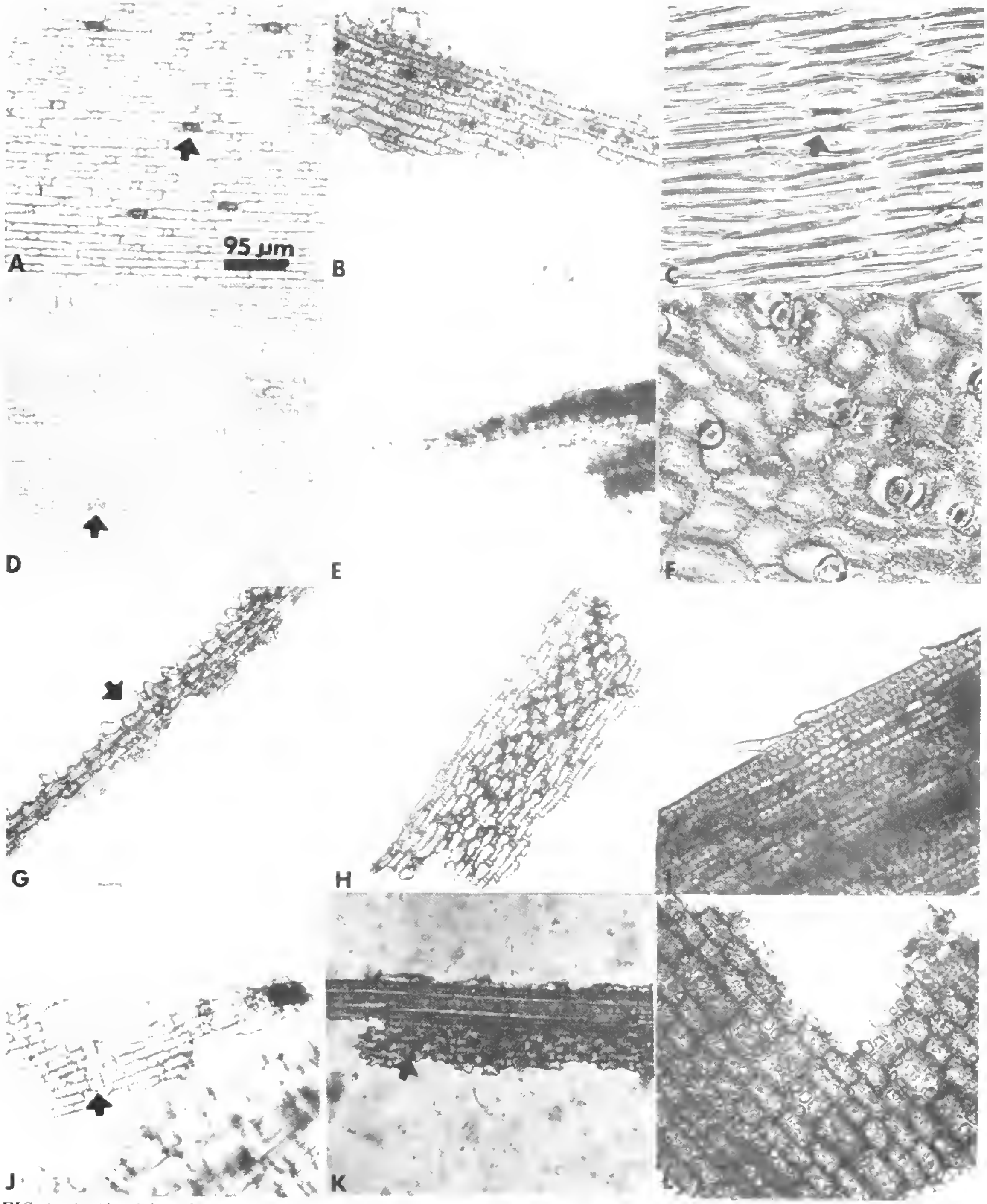

FIG. 1. **A)** Abaxial epidermis of *S. alterniflora* showing rectangular long cells, abundant solitary short cells and stomata (arrow) in longitudinal rows; **B)** adaxial epidermis of *S. alterniflora* showing rectangular cells covered with multiple rows of small papillae; **C)** leaf surface of *Limonium carolinianum* showing elongated cells and sunken stomata (arrow); **D)** abaxial epidermis of *S. patens* showing rectangular long cells alternating with short cells and scattered stomata (arrow); **E)** adaxial epidermis of *S. patens* showing rectangular cells covered with single rows of papillae; **F)** leaf surface of *Salicornia europaea;* **G)** large, conical papillae (arrow) on the adaxial surface of *D. spicata;* **H)** abaxial epidermis of *D. spicata* showing long cells with coarse sinuations between veins; **I)** fragment of *Ruppia marina;* **J)** abaxial epidermis of *J. gerardi* showing large, abundant stomata (arrow); **K)** abaxial epidermis of *Phragmites australis* showing coarsely sinuated walls and hooked-shaped prickle hairs (arrow); **L)** fragment of *Zostera marina.*

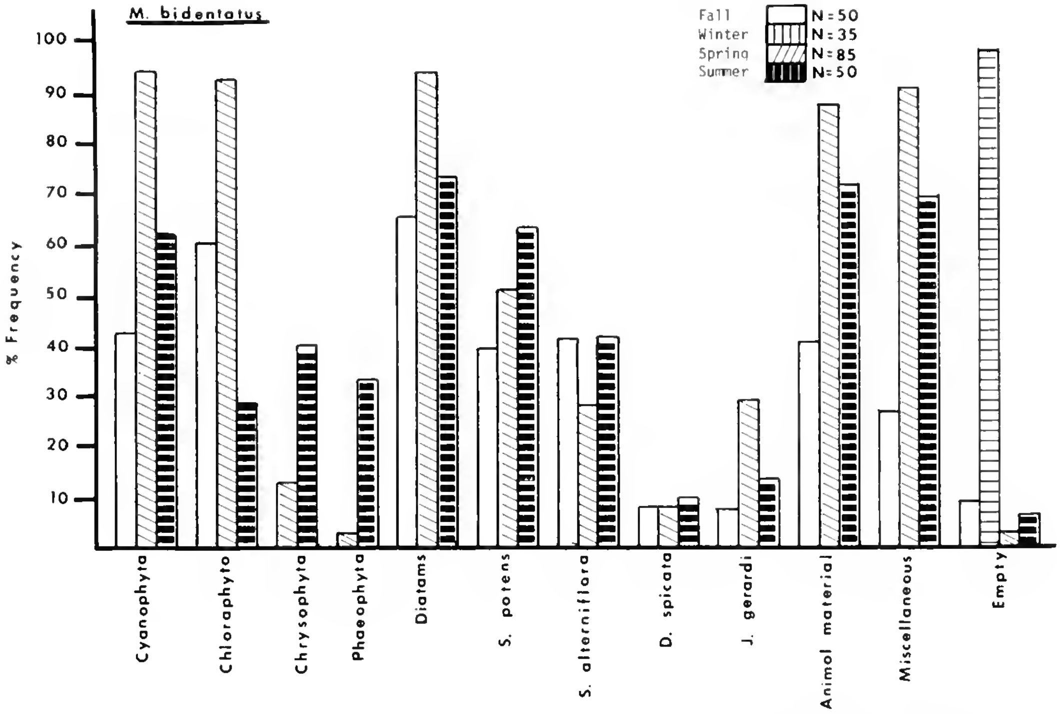

FIG. 2. Percent frequency of food items found in the gut contents of 220 *Melampus bidentatus*.

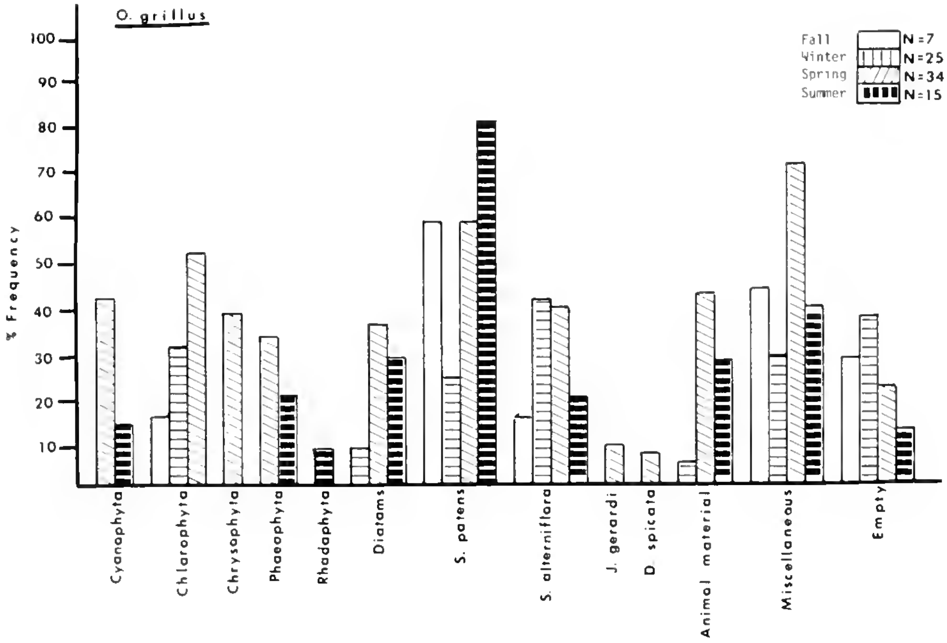

FIG. 3. Percent frequency of food items found in the gut contents of 81 *Orchestia grillus*.

buried beneath a layer of frozen peat. Those collected for gut content analysis, as well as the unpreserved specimens, ranged from 5 mm to 8 mm in shell length. The guts were all found to be empty. The unpreserved specimens that were transported back to the laboratory became active within 20 minutes after being placed at room temperature.

In the winter follow-up study, inactive *Melampus* with shell lengths greater than 8 mm, remained on the surface of the peat, singly or in clusters, during periods of mild weather. However, when maximum air temperature or the temperature of the peat dropped below 0°C, or during periods when the marsh surface was covered with ice and/or snow (as shown in Fig. 4 in mid-January and throughout February and early March) these large-size snails became partially embedded along *Spartina* stems. When the ice and snow disappeared or the temperature of the air and peat rose, *Melampus* were again found on the surface. Snails smaller than 8 mm did not appear on the marsh surface until April when both air and peat temperatures began to steadily increase; apparently they were buried in deeper layers of peat during cold weather. But even though it appears that *Melampus* does move somewhat during the winter, all specimens dissected for gut content analysis were found to be empty as in the previous study. Hence, there is no direct evidence that *Melampus* feeds during the winter.

Contrary to the apparent inactivity of *Melampus*, *Orchestia*, although moving more slowly than usual, was active under piles of flotsam during the winter. And while food was present in the gut of *Orchestia* during this period, the quantities were smaller than in other seasons. Much of the grass removed for examination was in an advanced state of decomposition, hence, it could not be identified. Forty percent of the amphipods did contain identifiable *S. alterniflora* fragments and 39% had consumed *Ulva lactuca* which had washed onto the frozen marsh surface and was covering large portions of the up-

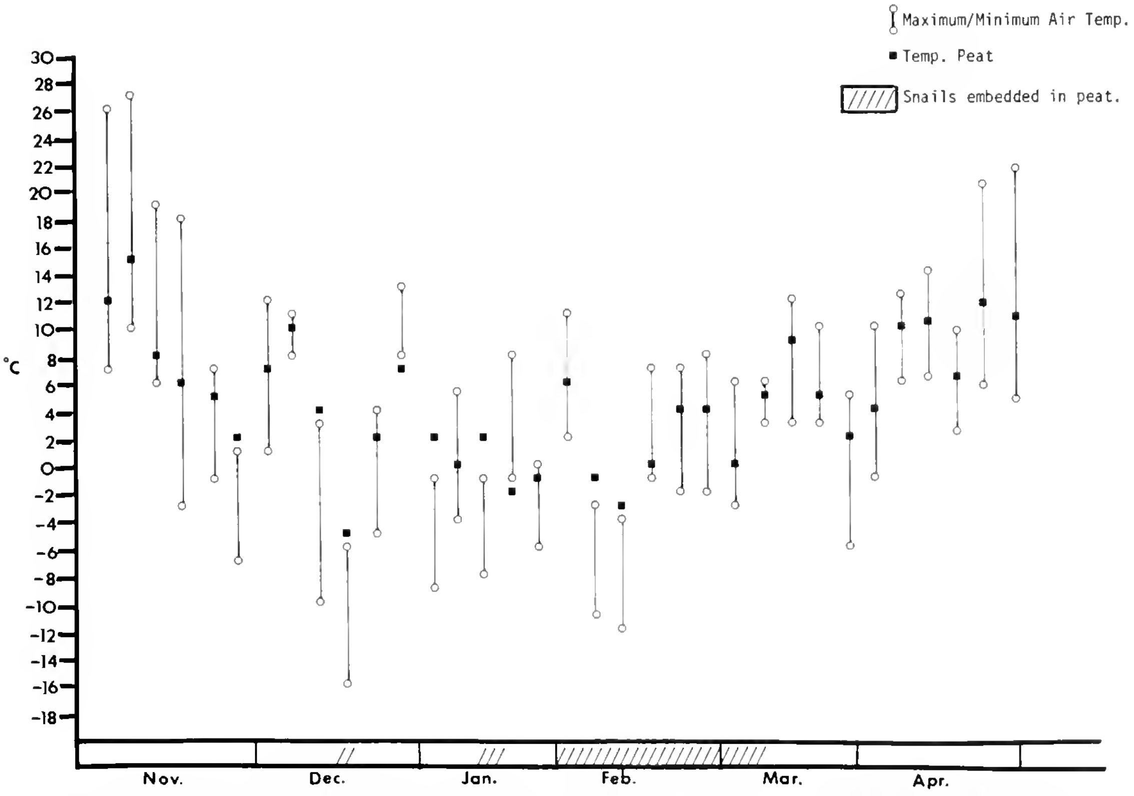

FIG. 4. Maximum and minimum air temperatures, peat temperatures and position of *Melampus bidentatus* on high marsh from November through April, 1982-83.

per regions.

Analysis of fecal contents showed the presence of grass epidermal cells, diatoms, intact algal trichomes, as well as empty sheaths, and undigested animal material. These findings seem to indicate that much of what is consumed by *Melampus* and *Orchestia* is deposited back on the marsh, although grass and macroalgae are in somewhat smaller fragments due to mastication and/or trituration.

While tabulations of percent frequency indicate that both animals are generalists in their dietary preferences, they do not give an accurate picture of important food sources. For example, diatoms were consumed by 74% of the snails but because of the small sizes of these items, they rarely accounted for more than 5% of the total food content per gut. Estimations of percent volume of various food items per gut (Fig. 5) indicate that grass detritus, especially *S. patens* and *S. alterniflora*, is the major food component. In both *Orchestia* and *Melampus* these two grasses accounted for more than 60% of the total gut content per snail. All other food items, including algae, diatoms and animal material, contributed to the remaining 40%.

Several plant species such as *Phragmites australis, Ascophyllum nodosum, Limonium carolinianum* and *Salicornia europaea*, although abundant on the marsh, were not observed in either gut contents or fecal samples. Fragments of these species may have been consumed but were too small to be identified or were too decomposed or macerated for specific features to be recognized. Overall, the percent frequency of unidentifiable material found in the gut averaged 6% in *Melampus* and 9% in *Orchestia;* however, it constituted less than 1% of the overall percent volume.

Figures from this study indicate that approximately 60% to 65% of the diets of *M. bidentatus* and *O. grillus* are composed of salt marsh grass detritus consisting mainly of *S. patens* and *S. alterniflora*. The remaining bulk of the diet is made up largely of a variety of algal species which become seasonally available. Animal material, while frequently ingested, does not contribute much bulk to the diet because of the small amounts consumed by each animal.

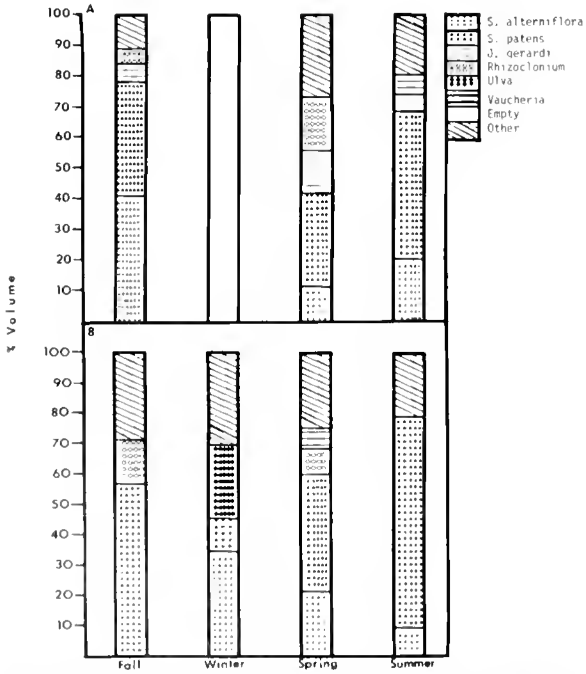

FIG. 5. A) Percent volume of major food items in *Melampus bidentatus* calculated per animal; B) percent volume of major food items in *Orchestia grillus*. "Other" category refers to all items constituting less than 5% of total gut content which includes unidentifiable material.

Discussion

Although *M. bidentatus* uses a radula to "lick" small food particles from the marsh surface and *O. grillus* bites off large chunks of solid material and masticates them with mandibles, both animals are opportunistic feeders with very similar diets. Potential nutritional value of a food item seems to be of little importance since a large part of what is ingested, such as epidermal cells from grasses and animal chitin, appears to be indigestible and ultimately ends up in the feces. The fact that both species can exist in the same area and eat the same food substances is probably due to the large amount of detritus available on the high marsh. For example, 42,000 tons of plant material are produced annually on 6,277 hectares of Connecticut marsh land (Niering and Warren, 1974) and only a small percentage of this production is eaten while still alive.

It is evident from this study that *Melampus* and *Orchestia* feed primarily on decaying grass fragments and in particular on *S. patens* which is the dominant plant species on Watts Island. The fact that fresh grass particles were never

found in the guts analyzed correlates with a laboratory study conducted by Valiela *et al.* (1979) which showed that when *M. bidentatus* and *O. grillus* were presented with new *S. alterniflora* detritus as opposed to nine-month-old dead grass, feeding activity decreased. Their findings indicate that the animal's feeding is inhibited by high concentrations of ferulic and *p*-courmaric acids in the fresh material which decrease as the grass ages. In the present study *Melampus* that were offered fresh particles of various grass species refused to eat the plant material but did consume the seawater soaked filter paper lining the petri dishes in which they were being held. Hausman (1932) stated that microscopic examination of the stomach contents of actively feeding *Melampus* showed a large quantity of epidermal cell fragments of marsh grasses, but in a 1936 paper she reports that the proportion of higher plant tissue in the diet is small.

In this study it has also been shown that although algae were regularly consumed, there appears to be no set preference for one species over another; the species consumed most frequently and in the largest quantity was also the most abundant on the marsh at the time. For example, *Rhizoclonium riparium* had the highest percent frequency of consumption and percent volume per *Melampus* gut in the spring, but it was replaced by *Vaucheria* spp. and the filamentous blue-green algae in the summer. Diatoms had an overall percent frequency of 69% with a maximum of 94% in *Melampus* in the spring but the percent volume per gut was never more than 5%. Hausman (1936) stated a figure of 75% algae consisting chiefly of diatoms which more closely correlates with the percent frequency figures from the present study rather than proportion of material per gut which is quoted in her paper.

While *Melampus* is primarily an herbivore, it is an opportunistic feeder sometimes ingesting animal material. Although percent frequency of ingestion of animal material in this study reached 76% in some instances, the percent volume of such material rarely accounted for more than 1% of the total gut content per snail. Hausman (1936) also reported the presence of animal components in the gut contents of *Melampus*.

Although there is no evidence from gut content analysis in this study that *Melampus* feeds during the winter, Hausman (1948) reported that on warm winter days the snails emerge from their cover to feed on nearby mudflats. No such activity was observed in either of the present winter studies. Grandy (1972) reported a lack of movement of *Melampus* beginning in mid-November in a Cape Cod salt marsh. But evidence from this study indicates that *Melampus* is not completely dormant. For instance, large-size snails were usually found to be inactive on the surface of the peat, but they actively sought cover when the temperature of the air and/or peat dropped or when the marsh surface was covered with ice and/or snow. Hausman (1948) also reported that when air temperatures averaged about −7°C, snails in a Connecticut marsh moved under thick tufts of *Spartina*, which corresponds to the findings in this study.

The lack of smaller-size *Melampus* on the marsh surface during the winter indicates a possible lack of tolerance of these animals to cold temperatures. This correlates to findings by Price (1980) who reported a mortality rate of 85.7% in *Melampus* measuring less than 5 mm after 3 days of being exposed to air temperatures of −12°C. This rate decreased to 68.8% in snails measuring 5 to 7 mm and 26.7% in those larger than 8 mm, indicating an increased tolerance to cold with size increase (Price, 1980).

Results from this study indicate that *O. grillus* is also a generalized feeder, indiscriminately ingesting whatever is available. For example, during the winter when the marsh surface was covered with ice, *O. grillus* readily switched from eating grass detritus and consumed decaying *Ulva lactuca* which had accumulated along the upland border instead. And while there are no indications that *Orchestia* attacks live animals, Smallwood (1905) stated that in confinement they will eat one of their own species that happens to die.

Further quantitative studies need to be made to determine what components of the diet are being assimilated and what impact the consumption of large amounts of detritus by invertebrates has on the marsh ecosystem. Haines and Montague (1979), for instance, in tracing carbon sources through a salt marsh food web in Georgia, found that the $\Delta^{13}C$ values in *M. biden-*

tatus correspond closely to the values for *S. alterniflora*. In the present study contents of the feces in both species were very similar to the gut contents. This fact indicates that much of the material consumed by *Melampus* and *Orchestia* is redeposited on the marsh and suggests that a substantial portion of their nutrition may be derived from the bacteria growing on the surface of the food particles and not from the detritus itself. Darnell (1967) and Odum and de la Cruz (1967) found that large microbial populations grow on detrital particles and constitute an energy-rich source for organisms capable of removing them. Hargrave (1970), in feeding experiments on the amphipod *Hyatella azteca*, found an assimilation efficiency of 60% to 82% with bacteria and diatoms but only 5% to 15% with blue-green algae. The gut contents of *Ilyanassa obsoleta*, a snail inhabiting sandflats, were found to consist largely of sediments, leading Curtis and Hurd (1981) to conclude that most of its nutrition is apparently derived from microflora growing on the sediment. And Daiber (1982) notes that *O. grillus* feeds primarily on the fungus covering grass detritus, frequently scraping off and ingesting fragments of grass from below the fungal layer.

Because of the large numbers of these two invertebrates on the high marsh and the large amount of detritus that is broken down by them during mastication and/or trituration and deposited back on the marsh, they may have a significant effect on raising the nutritional value of the detrital particles that are washed into estuarine waters by tidal action to serve as direct or indirect food sources for offshore species. Teal (1962) in a Georgia salt marsh study, found that only 55% of primary productivity is assimilated by consumer species with 47% being dissipated by bacteria, 7% by primary consumers and 0.6% by secondary consumers; the remaining 45% is apparently exported to estuaries. Odum and de la Cruz (1967) found that smaller particles of detritus are richer in protein than large particles; small pieces have an increased surface-to-volume ratio for greater bacterial growth which accounts for the enrichment. On an ash-free basis small suspended particles were found to contain 24% protein compared with 10% in living grass and 6% in dead grass (Odum and de la Cruz, 1967). Certainly much of the food material which passes through the guts of *M. bidentatus* and *O. grillus* can be reingested and recycled over and over again, allowing microbial decomposition and surface absorption to occur between passages.

Evidence from this study indicates that both *M. bidentatus* and *O. grillus* are generalized, opportunistic feeders, consuming large quantities of salt marsh grass production, much of which is broken into smaller pieces during digestion and deposited back on the marsh. Further quantitative studies need to be made to determine what impact these two invertebrates have on the total marsh ecosystem as well as what components of their diets are being assimilated.

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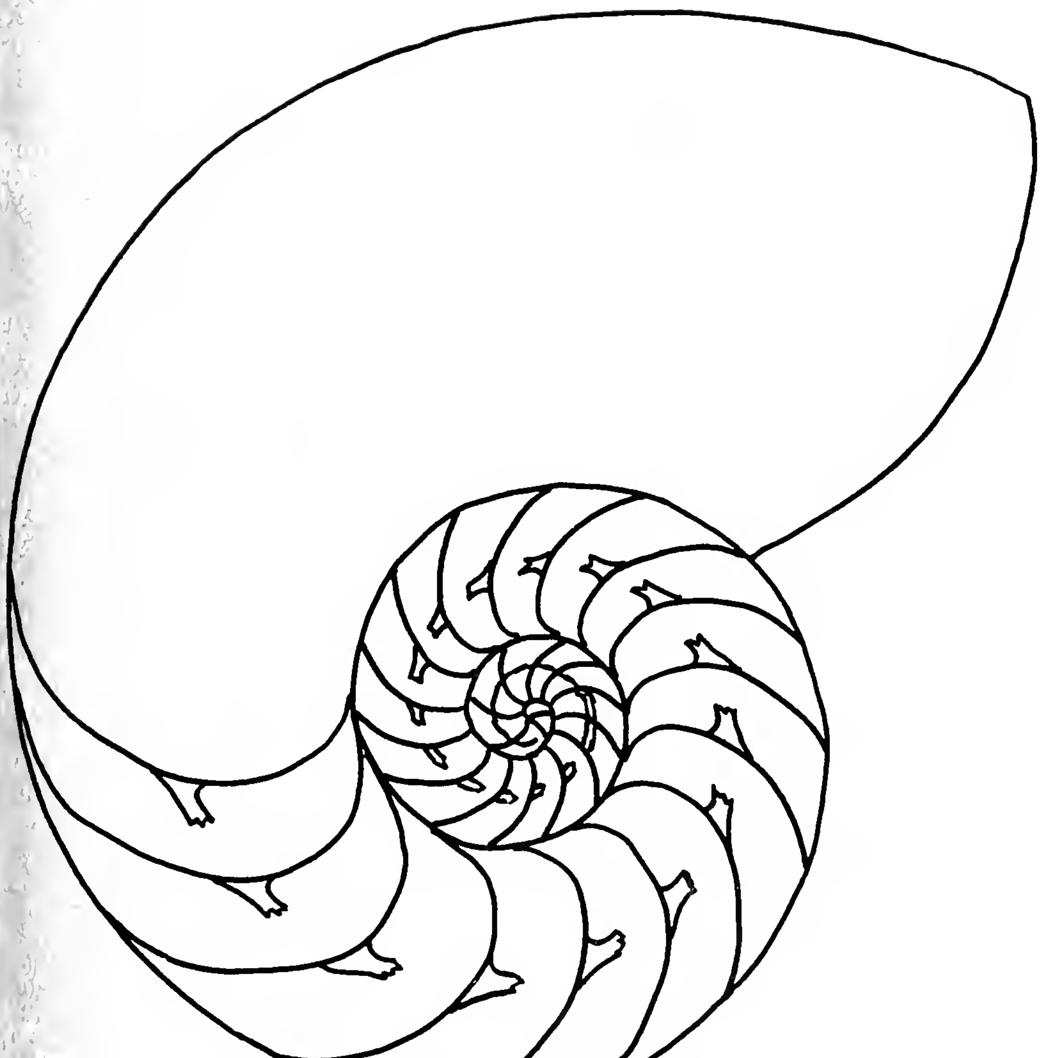

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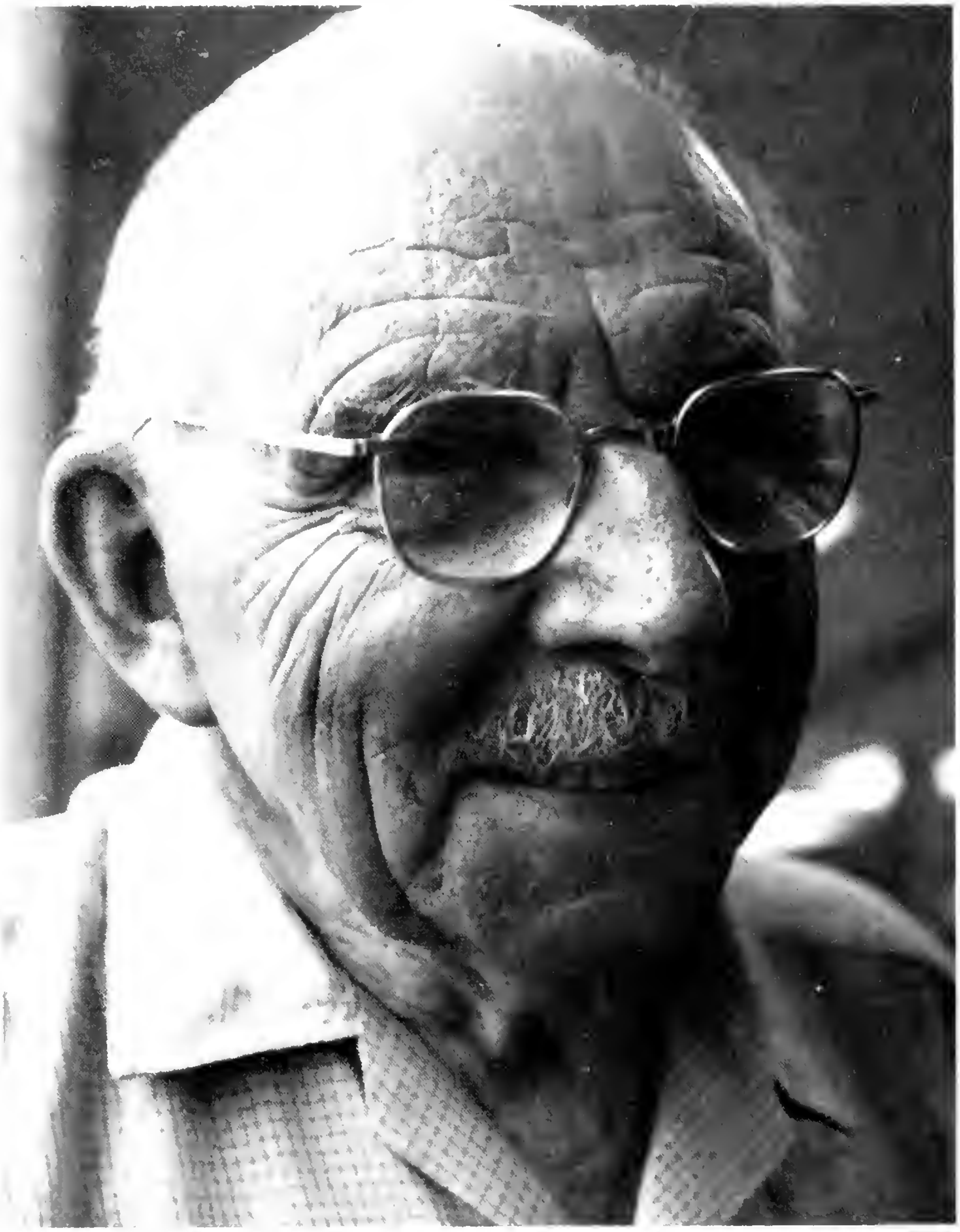
CONTENTS



WILLIAM J. CLENCH (1897-1984)

A FAREWELL TO BILL CLENCH

In our relatively small field of malacology no man made a greater personal impact over the last 60 years than did Bill Clench. He had not the knowledge of Pilsbry, nor the brilliance of H. B. Baker, not the cleverness of Bartsch, nor the precision of Myra Keen, yet he produced dozens of successful students, set modern standards for curatorial procedures, gave birth to new mollusk journals, made over 2,500 collecting stations, and inspired three generations of amateurs to contribute their time and energies to helping our science.

Bill was a gregarious, but thoughtful, extrovert. He loved people and he loved his students whom he instructed on a one-to-one basis. He had a friendly charisma that drew most people within his spell. Bill was a fatherly

hero to many budding malacologists, but human enough to have feet of clay. He often said that if a student could not go beyond the capabilities of his teacher, the student was not worth his weight in salt.

Bill himself had several heros – Charles W. Johnson, Bryant Walker, Henry Pilsbry and Matt Dillon of "Gunsmoke." As a young boy, he roamed the area around Blue Hill, south of Boston, where he collected insects and mollusks. The first mollusk he ever collected was a *Triodopsis albolabris* (curiously, also the first species ever collected by C. R. Orcutt, and the first species ever described by Thomas Say). Bill took his unidentified treasures into the Boston Society of Natural History where kindly and patient Johnson schooled Bill in natural history.

Their association was a long and close one, and during the last years of Johnson's life, Bill assisted him in the business managing of *The Nautilus*, and after Johnson's death, he edited and sent to the printer Johnson's famous, *Marine Mollusca of the Atlantic Coast from Labrador to Texas*. By a quick coup by Pilsbry, the business managership of *The Nautilus* returned to Philadelphia. Seven years later, Bill launched a new monographic series and named it *Johnsonia* after his boyhood idol.

Bill Clench, at age 49, in Cambridge, Mass., in December 1946. *Johnsonia* was in its second volume, *Occasional Papers on Mollusks* had just been launched, and his two students at the time were Ruth D. Turner and Isabel Farfante.

Bill Clench, at the age of 35, on a *Liguus* hunt with Henry A. Pilsbry, age 70, at Hammock no. 38, Long Pine Key, Florida Everglades, on March 13, 1931. For an account of this trip, see *The Nautilus*, vol. 45, pp. 10-15, July 1931.

Bill Clench entered Michigan State College in East Lansing just as America was about to enter World War I. Years later he would regale his friends and students with boisterous tales of fraternity life at a mid-West cow college. He broke his nose showing off to the girls while ice-skating with his hands in his pockets; earned extra money by playing saxaphone with his own college group; and met and married his college sweetheart, Julia V. Helmick. She was a main stay in his life and tolerated his consuming passion for malacology. She was the only person who repeatedly listened to Bill's famous old jokes and stories as if each telling was new. Julia kept the home fires burning during lonely vigils while Bill was on field trips, and she was a second mother to some of Bill's students.

It was during his graduate days in Ann Arbor that Bill came under the beneficial influence of another idol of his – Bryant Walker, a well-to-do lawyer in Detroit who was an accomplished

malacologist. Walker lit the malacological fires within Bill and was largely responsible for his first love, the freshwater mollusks.

As a field director, Clench had few rivals. *The Nautilus* abounds with his accounts of early trips to the rivers of the Southeast and the Everglades of Florida. Many of his early students received their baptism of fire on Clench's expeditions to the Bahamas, Santo Domingo and Cuba. Nearly every one of his students spent some time in the field with him. The collection at Harvard grew tenfold under his curatorship from 1926 to 1966. He made his 2,500th field station in Florida at the age of 85. He was an omnivorous collector, but took greatest delight in collecting *Cerion*, *Liguus*, pleurocerids and unios.

Bill had a great appreciation of the history of malacology and felt a personal closeness with the earlier workers. Many of the numbers in his *Occasional Papers on Mollusks* were devoted to the biographies of the malacologists that had gone down the same science trails. He took delight in telling his students about the lives and foibles of his early associates, such as William Morton Wheeler, Arthur F. Gray, Norman Lermond and Tom Barbour. He often recalled his visit with the South Carolina malacologist, William Mazyck, in the 1930's. Elderly Mazyck had corresponded with other malacologists for years, but Bill was his first mollusk visitor in 50 years. When Mazyck heard the malacological terms and names rolling off Clench's tongue, the tears ran down the old man's cheeks.

If the many students gained much from Bill, it was certainly true that he, in turn, received a great deal of support through the years from those around him. Dick Foster made it possible to launch *Johnsonia* and also financed a number of Bill's projects; "Uncle Joe" Bequaert, a colleague, supplied him with translations of foreign languages; Ruth Turner, with her great talents in dissecting and illustrating, co-authored many of his better papers; Dave Stansbery and Henry Russell often went out of their way to furnish transportation for many of Bill's trips; and Dr. Merrill Champion proofread and created indexes for his publications.

Bill was a great correspondent. During World War II he wrote over 2,500 letters to his students serving in the Armed Forces. It would be impossible to innumerate the number of friends to whom he sent postcards and letters during his lifetime. On field trips, long after other expedition members had turned in, Bill could be found sipping on beer and scratching out postcards in the light of a lantern. At home, after he had finished a nightime project, he would sometimes write letters until two in the morning.

Three tragedies occurred in Bill's later life that seemed to slow him down. His wife, Julia, died in 1969 after minor surgery, while she was in her late sixties. It created a void that was never filled. A few years later his eldest son, Harry, the well-known lepidopterist at the Carnegie Museum in Pittsburgh, died of a heart attack. He lost a fellow naturalist, as well as a kindly son. About the age of 82, Bill experienced a minor stroke. His handwriting and grammar took a turn for the worse. His memory for cer-

"It's more fun snaking out unios by the mitful in a place like Lake Waccamaw!," was the typical comment made by Bill Clench while collecting, at age 73, in North Carolina. Photo by Paul Jennewein, July 1970.

tain words failed him. After a throat operation in 1983, he was placed in a rest home in California near his son, Carleton.

We must all cross that River Styx someday. Most malacologists will be destined forever to an eternity of measuring shells, re-working their own synonymies, or color-coding their electrophoresis test tubes, but Bill Clench will be criss-crossing those sunny Elysian fields collecting new species of unbelievable abundance and beauty. And at his feet will gather a new and eager parade of mollusk students.

On a frosty February morning, in 1984, the boatman came for William James Clench. Across the River Styx they slowly poled the boat, and by the time they were half way across, Bill had already lost his aged stoop, he was once more in his youthful collecting duds, and eager to join his old friends. On top of the far bank six figures beckoned him on – Charlie Johnson and Bryant Walker, "Uncle Joe" Bequaert, Harry Clench with butterfly net in hand, Dick Foster who had leased a whole steam engine train for the occasion, and finally his wife Julia, thoughtful as ever with a picnic basket and case of beer at hand.

I can report that Bill gave a last farewell wave, like Matt Dillon riding into the sunset. Bill drew a huge arrow in the sand pointing up the bank. It was for his other students due someday to follow – Harald Rehder, Alan Archer, Henry Russell, Dick McLean, Tucker Abbott, Dick Johnson, Ruth Turner, Yoshio Kondo, Isabel Farfante, Joe Rosewater, Tom Pulley, Arthur Merrill, J. Lockwood Chamberlin, Joseph Vagvolgyi, Ed Michelson, Bob Bullock, Ken Boss, Robert Robertson, Arthur Clarke, Don McMichael, Sam Fuller, Vida Kenk, and Barry Wilson.

The train was packed with his old friends. They had all been waiting a long time, and were all impatient to set off with Bill for an endless day of collecting *Cerion*, *Liguus*, *Io*, and foot-long, spiny unios.

On the following day his son, Carleton, sent the news from California:

William J. Clench, 1897-1984

Early in the morning of February 22nd the world lost a fine person, the scientific community lost an eminent malacologist and I lost my dad. His passing was calm and dignified.

R. Tucker Abbott
Melbourne, Florida

CONUS KINTOKI HABE AND KOSUGE, 1970: A VALIDLY PROPOSED TAXON

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ABSTRACT

The nomenclatural status of Conus kintoki *Habe and Kosuge, 1970, is reviewed and this taxon is determined to have been validly proposed.* Conus kintoki *Coomans and Moolenbeek, 1982, is a junior subjective synonym. A specimen of this cone is illustrated.*

A number of authors have commented on the status of the nominal species *Conus kintoki* Habe and Kosuge (1970:9). Most of these writers have questioned the availability of this name under the provisions of the International Code of Zoological Nomenclature (Walls, 1979:350; Tucker, 1980:9, no. 26; Martin, 1982:4; and Sage, 1982:9). Kosuge (1979:21),

subsequent to his 1970 paper, considered *C. kintoki* Habe and Kosuge a *nomen nudum*. Coomans and Moolenbeek (1982:136, 137, fig. 1), in the belief this taxon was a *nomen nudum*, "validated" the name by proposing: "*Conus kintoki* nov. spec." Tucker (1983:5) subsequently suggested that the name should date from the earlier citation to "*Conus kintoki* Habe" made by Kaicher (1977: no. 1303) on an identification card. As a result of the conflicting views concerning the availability of the name, *Conus kintoki*, a review of the nomenclatural status of this taxon was undertaken.

Nomenclatural Status

Conus kintoki was proposed by Habe and Kosuge in "Pacific Shell News– " (40 pp., April 30, 1970), a popular publication with text in both Japanese and English and with illustrations of the species discussed.

In the Table of Contents, under the heading "New Species" (in English), the description of the taxon *Conus kintoki* (in Japanese ideograms) is cited for page 9. On page 9 is found the latinized species name, "*Conus kintoki* Habe et Kosuge", heading the brief descriptive text, part of which is in Japanese and part in English. An apertural view of the shell of *Conus kintoki* is also illustrated on page 9.

The Japanese text on page 9 reads:

"Since the shell is solid and has a thick shell epidermis, it seems to live in shallow water. But it was collected from the South China Sea at 200 m depth. After the shell epidermis is removed, we can see a fairly beautiful shell, which is colored with flesh yellowish pink. I gave the Japanese name (Kintoki Cone) because the color of the shell reminds me of the 'Sakata's Kintoki' [a mythological Japanese baby warrior with a yellowish pink complexion]. This species resembles *Virgiconus virgo* [name in Japanese ideograms] in appearance, but the base (anterior part) of this new species is not stained with dark purple as in *V. virgo* [name in Japanese ideograms]. Additionally, the color of this shell appears quite distinct from the others (S. [adao] K. [osuge])".

The text in English on page 9 follows:

"This new cone shell comes from the South China Sea at about 200 m depth. The description of the species will be appeared [*sic*] in the Venus, Jap. Jour. Malac. Measurement: 102.0 × 49.5 mm."

At my request, Dr. Melville kindly reviewed the pertinent references to the use of the name, *Conus kintoki*, and he has permitted me to quote his comments on the availability of this name:

"I now conclude that the name was made available by Habe & Kosuge, 1970, *Pacific Shell News* No. 2, p. 9, for the following reasons:

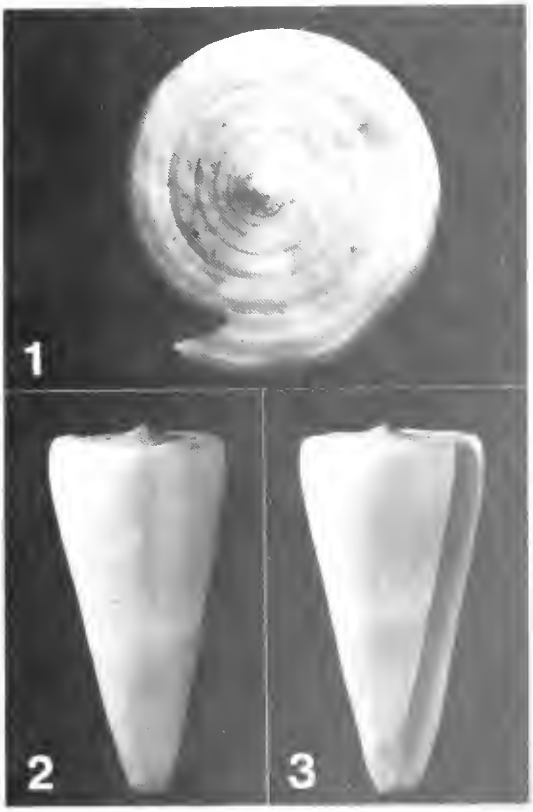
– the name is published (Art. 11a).
– the name is latinised (Art. 11b).
– the (specific) name is a noun in apposition (Art. 11g(i)(2).
– paragraph 2 of the description beginning "This shell resembles *Virgiconus virgo*" purports to differentiate the species and thus satisfies the provisions of Article 13a(i) for names published after 1930.

"Since these objective criteria are satisfied, there is no reason to reject the name as unavailable. Subjective criticisms of the adequacy of the description may affect the validity of the name, or even lead to its being treated as a *nomen dubium*, but these considerations do not affect its availability."

Although for personal reasons, Drs. Habe and Kosuge did not redescribe this taxon in the *Venus* or elsewhere, their original description in "Pacific Shell News" in my opinion is *ipso facto* a valid proposal of a new species. *Conus kintoki* Habe and Kosuge, 1970, hence, is an available name for populations of this cone that are known from the Philippines and the South China Sea. This taxon, therefore, should date from Habe and Kosuge, 1970, and should not be attributed to *Conus kintoki* Coomans and Moolenbeek, 1982, despite their good intentions to "validate" the name.

The only condition one might raise to question the availability of Habe's and Kosuge's nominal species is that new names proposed "conditionally", after 1960, are not available (Article 15 of the I.C.Z.N.). In the sense of the Code, however, the authors of this taxon clearly recognized it as a new species, which did not require additional documentation, such as more or better preserved specimens, or the need for any additional data. The co-authorship of this taxon is clearly established by the use of "*Conus kintoki* Habe et Kosuge" (1970:9), regardless of the fact that Dr. Sadao Kosuge's initals, "(S.K.)", follow the Japanese text of the species description.

Conus kintoki (here illustrated, Figures, 1-3), is a member of an Indo-Pacific species complex including: *Conus coelinae* Crosse, 1858, *C.*



FIGS. 1-3. *Conus kintoki* Habe and Kosuge, 1970. Purchased in Taiwan (probably trawled in the South China Sea), ex. T. H. and V. B. Munyan coll., AMNH 201677. Fig. 1, × 1, figs. **2**, **3**, × ½.

spiceri Bartsch and Rehder, 1943, and *Conus berdulinus* Veillard, 1972. See Walls (1979:347, 350), Coomans and Moolenbeek (1982a:136, 137; 1982b:19, 20) and Martin (1983:4) for comments on the taxonomy of this poorly known complex.

Acknowledgments

I am greatly indebted to Mr. Yoshimi Fujioka of the Mukaishima Marine Biological Station, Hiroshima University, Hiroshima Pref., for kindly providing me with an English translation of the Japanese text. I thank Dr. Henry E. Coomans of the Zoologisch Museum, Amsterdam, for his comments on the English translation, which I transmitted to him in November, 1982. I am most grateful to Dr. R. V. Melville, Secretary of the International Commission of Zoological Nomenclature, for critically reading a draft of the manuscript and offering his opinions on the interpretation of certain provisions of the Code. I also thank my AMNH colleagues: Ms. Kathleen Marius for word-processing the manuscript, Mr. Walter E. Sage, III for technical assistance, and Mr. Jeff A. Teitelbaum for the photography.

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SEX RATIO IN THE SOFT-SHELL CLAM, *MYA ARENARIA*

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ABSTRACT

The sex ratio in Mya arenaria, *the soft-shell clam, was studied using samples collected from 25 populations. The sex ratio was found to be significantly biased in favor of females (52% F: 48% M). The advantages of, and mechanism maintaining, such a bias remain enigmatic.*

In previous studies on *Mya arenaria* Shaw (1965), Pfitzenmeyer (1972), Porter (1974), and Brousseau (1978b) all reported that the sex ratio was unbiased. Porter was the only one to give actual figures: 52% female. To statistically verify such a small bias in sex ratio on the basis of one sample would necessitate a sample size of over 1200 individuals (X^2, *d.f.* = 1, p = .05). Recently, a survey of 25 soft-shell clam populations throughout the northeast coast of North America was made, involving the collection of over 5,000 individuals (Brown *et al.*, 1977). Histological sections obtained from this study were used to investigate the sex ratio in *Mya arenaria*.

Methods

Sex proportions were calculated for each population by comparing the number of females to the total number of sexed individuals. All sex determinations were based on histological examination of the gonads.

Results

The results are presented in Table 1. From the table it can be seen that in the majority of populations females outnumber males. The overall proportion of females was 52.1% for the entire sample and 52.3% averaged by area. The null hypothesis of equal sex ratios among all samples was tested using a binomial test (Hollander and Wolfe, 1973). The test showed that the number of female biased populations (18) was significantly greater than the number which were male biased (6) so the null hypothesis was rejected (T* = 2.45, p = .007).

TABLE 1. Sex ratio of *Mya arenaria* observed at each site N = number of sexed clams.

Sampling Site	% Females	N
Tangier Sound MD	4.97	167
Big Annemessex River MD	57.8	166
Navesink River NJ	48.9	180
Raritan Bay NJ	50.0	194
Winnapaug Pond RI	55.3	170
Quonochontaug Pond-1 RI	56.7	60
Quonochontaug Pond-2 RI	49.1	159
Saugatucket River RI	54.2	144
Wickford RI	54.7	190
Allen Harbor RI	53.3	283
East Greenwich Cove RI	51.6	310
Watchemoket Cove RI	64.6	82
New Bedford MA	48.1	156
Bourne MA	50.3	159
West Falmouth MA	52.7	186
Coonamessett River MA	51.1	133
Portland ME	54.3	162
Long Cove, Searsport ME	52.7	693
Stockton Harbor ME	48.1	156
Goose Cove ME	52.2	161
Deer Isle ME	50.3	159
Robinston, ME	50.3	185
Perry ME	46.7	167
Janvrin Lagoon NS	51.9	183
Potato Island NS	53.5	198

To test whether the sex ratio varied with age, populations with similar growth rates (Appeldoorn, 1983) were pooled and trends in the sex ratio with size were examined. Two composite groups were formed: Wickford-Winnapaug Pond and Watchemoket Cove-Portland-Allen

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Harbor-Quonochontaug Pond-1. Table 2 shows the results. In the former group the proportion of females increased with size while in the latter group it decreased with size.

Discussion

Unequal sex ratios are not uncommon in mollusks, including bivalves, and Fretter and Graham (in Wilbur and Yonge, 1964) stated that females tend to outnumber males in gonochoristic species, such as *Mya*. Some examples of percent females found in bivalves are: *Cardium* (=*Cerastoderma*) *edule* 60%; *Donax vittatus* 55%; *Tellina* (=*Macoma*) *balthica* 53%; *T. fragilis* 53%; *Scrobicularia piperata* 59%; *Pholas candida* 55%; and *Anodonta cygnea* 54% (Pelseneer, 1926). Normally in these species the disparity was not present in the young but increased with age. It was assumed to result from a higher mortality rate for the males (Pelseneer, 1926). Brousseau (1978b) reported no change in the sex ratio of *Mya* as a function of size, and the contradictory trends evidenced here, in Table 2, preclude any meaningful interpretation that could either support or refute this assumption.

Coe and Turner (1938) observed indications of bisexuality in the differentiated gonads of young soft-shell clams. Ropes (1982) theorized that sexuality in *Mya* may be under some environmental control which could affect both population sex ratio and the incidence of hermaphroditism, and that in stressful environments deviations from the norm should co-occur. In an analysis of Otto's (1973) data he reported no significant sex ratio bias existed within the samples containing hermaphrodites. Reexamining these data it was found that in 6 of the 7 samples having a biased sex ratio males predominated. Using the Wilcoxon signed rank test (Hollander and Wolfe, 1973) this predominance of male biased samples was found to be significant ($T^+ = 25.5$, $p = .039$). On the basis of the data in Table 1 this male bias is anomalous. That it coincides with a high incidence of hermaphroditism may support Rope's hypothesis.

The maintenance of biased sex ratios in higher vertebrates, such as man, is well understood in terms of genetic theory (Fisher, 1958; Williams, 1966); but in invertebrates, where several genes and environmental influences may be involved in sex determination, the origin and maintenance of a biased sex ratio is poorly understood. Wildish (1976) has developed general theoretical models which may explain the evolution of sex ratio biases in terms of *r*-and *K*-selection theory. However, they are of limited use here as *M. arenaria* cannot be strictly classified as either an *r*- or *K*-strategist (Brousseau, 1978a), and the underlying mechanisms resulting in biased sex ratios in *Mya* remain enigmatic. It is unlikely that uncontrolled field studies will be able to further define the role of the environment. Recent improvements in laboratory culture of *M. arenaria* (Hidu, 1981) may facilitate experimentation through environmental control and reduced genetic variability.

TABLE 2. Variation in the sex ratio of *Mya arenaria* as a function of size within pooled groups of samples.

Group = Wickford, Winnapaug Pond				
Length Interval (cm)	3-4.9	5-5.9	6-6.9	7-8.9
Sample Size	61	110	113	75
% Females	50.8	52.7	55.6	57.3

Group = Watchemoket Cove, Portland, Allen Harbor, Quonochontaug Pond-1				
Length Interval (cm)	2-3.9	4-4.9	5-5.9	6-8.9
Sample Size	143	182	118	85
% Females	59.4	57.1	54.2	42.4

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OBSERVATIONS ON A MICROPREDATOR, *GULELLA BICOLOR* (HUTTON) (GASTROPODA: PULMONATA: STREPTAXIDAE)

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ABSTRACT

A micropredator, Gulella bicolor *(Hutton), is the only member of the Streptaxidae found in the United States. It has been introduced to five known localities.* G. bicolor *in the New Orleans area was the subject of observations on food habits, population structure, and reproductive habits. It is associated only with man's activities, is a strict carnivore. Three groups of young appear from later May through mid-September or approximately every other month during the warm season. Growth rate is approximately 2 mm/month. The largest snail collected was 7.5 mm in height. Radula, "jaws", and digestive system all bear out the carnivorous habits of this species.*

This report presents findings on the habits and morphology of the snail, *Gulella bicolor* (Hutton) (Gastropoda: Pulmonata: Streptaxidae) in the New Orleans area. These minute snails (largest observed was 7.5 mm in length) comprise a portion of the introduced fauna of the United States and are the only U. S. members of this large snail family. They have been found in Charleston, SC; Coconut Grove, FL; Vicksburg, MS; and Boothville and New Orleans, LA. They were originally described from the Seychelles, Indian Ocean. The genus is one of the largest, containing many species in southern Africa, the presumed area of origin. *Gulella bicolor* occurs (as summarized by van der Schalie, 1948) also in South America, the West Indies, on some south Pacific islands, the Philippines and in the oriental region. Since these snails are part of our introduced fauna we must record any findings concerning them for future reference in case they should ever become a problem. To that end, we report some observations on habits and functional morphology.

Materials and Methods

All snails were collected live locally from fifteen localities in the New Orleans area. Since the snails are nowhere abundant, we merely collected for an hour in a given locality and used those snails as the bases for population structure studies.

Upon return to the lab, snails were measured (length × width), whorls counted and then

several snails were placed in Bouin's for shell decalcification and fixation for sectioning. The shells were completely decalified by the 3rd day at which time the entire animal was serial sectioned at 10 μ (cross, longitudinal, and sagittal sections). The animals are so small that entire serial sections will fit on 3 or 4 slides. Haematoxlyin-Eosin stains were used. The remaining specimens were preserved in 70% alcohol for using later for dissections. Cleaned snail shells were sputter-coated with gold-palladium and examined in a JEOL 35 C scanning electron microscope at 20 KV.

Habitat Type

In the New Orleans area *Gulella bicolor* appears to be "domesticated" in the sense of English sparrows and house mice in that they are associated only with man's activities. They live at the bases of building walls, around gravestones, along the edges of river wharves. We have never found them away from human activity areas even though they have been present for at least thirty years, which would seem to be a reasonable length of time for them to have dispersed to non-human habitats. They are almost always in shaded areas and are active only when the humidity is high. They are capable of withstanding desiccation up to at least 9 months as evidenced from one of our experiments. The soil in their habitats in the New Orleans area is often "crumbly" – the type often referred to by natives as "coffee grounds" soil. It is mostly dried organic material from pre-existing swamps.

Food

These snails are carnivores and feed on various soft invertebrates such as earthworms and on other small molluscs [subulinids (Mead, 1961) and pupillids]. These organisms occur in the same habitat with *G. bicolor* in this area. An experiment was designed to determine if *G.*

TABLE 1. Preferences of some introduced molluscs for selected habitat food items. (1 = eaten readily; 2 = eaten reluctantly; 3 = not eaten; * considered a carnivore under normal circumstances).

PLANT	MOLLUSCS (Gastropoda: Pulmonata)				
	**Gulella bicolor* (Hutton)	*Veronicella ameghini*	*Lamellaxis gracilis* (Hutton)	*Bradybaena similaris*	**Rumina decollata*
Ficus carica L. (fig tree)	3	3	3	3	1
Platanus occidentialis L. (sycamore tree)	3	3	3	3	3
Cinnamomum camphora (camphor tree)	3	3	3	3	3
Laportea canadense (nettles)	3	3	1	3	3
Lascacis diverticata (a tropical grass)	2	2	2	3	2
Panicum sp. (a grass)	3	2	1	3	2
Paspulum floridanum (knot grass)	3	3	3	3	3
Stenotaphrum secundatum (St. Augustine grass)	3	2	3	3	3
Gramineae (an unidentified grass)	3	3	3	1	3
Canna sp. (Canna lily)	3	3	3	1	1
Crepis aspersa (Hawksbill)	3	3	1	3	2
Doxantha unguis-cati (clawvine)	3	3	3	3	3

bicolor would eat vegetation.

Individuals were isolated for 2 weeks without food. Then they were each offered three intact leaves, stems, roots (Table 1) from each of the plants in their habitat. Other species of snails (Dundee, 1970) were also tested simultaneously. The experiments were run three times. As can be seen from Table 1, *Gulella* does not normally eat vegetation. The one case where it appeared that there was some radular rasping on *Lasceucis diverivata* leaves was possibly a misinterpretation on our part. The rasp marks were seen only the one time. Considering the type of radular teeth, it is not surprising that the snail do not accept vegetation; it would be very difficult for them to rasp and scrape vegetation.

Breeding Seasons and Population Structure

Since *Gulella bicolor* is nowhere abundant, the population study had to be based upon those few snails present in a given area. By sampling the population regularly we were able to determine approximate breeding periods and population structure for part of the year (Fig. 1). As seen in Fig. 1, there were, from April through October, three crops of young: late May, mid-to-late July, mid-September. Thus there is a new crop of young approximately every other month. New hatches are approximately 1.25 mm in length (height), 1 mm at the largest width, and have 3.25 whorls. The lip of the shell (Fig. 2) is not formed until after an individual has exceeded 4.75 mm in length (height) and has about 6.75 whorls. Growth in length, based solely upon the population growth rather than on individual growth, appears to be 3 mm per 1.5 months or approximately 2 mm per month. The largest snail found was 7.5 mm in length (height). Overwintering seems to occur in the adult stage (after the lip is present).

Shell and General Appearance

The overall morphology of the shell was examined by scanning electron microscopy. The shell (Fig. 2), the apertural teeth, (Fig. 2), and the umbilicus (Fig. 3) are seen without the living animal obscuring them. Living specimens often appear "two-toned" since they have a red-to-orange anterior and a yellow posterior (apex area), thus the specific name, "*bicolor*".

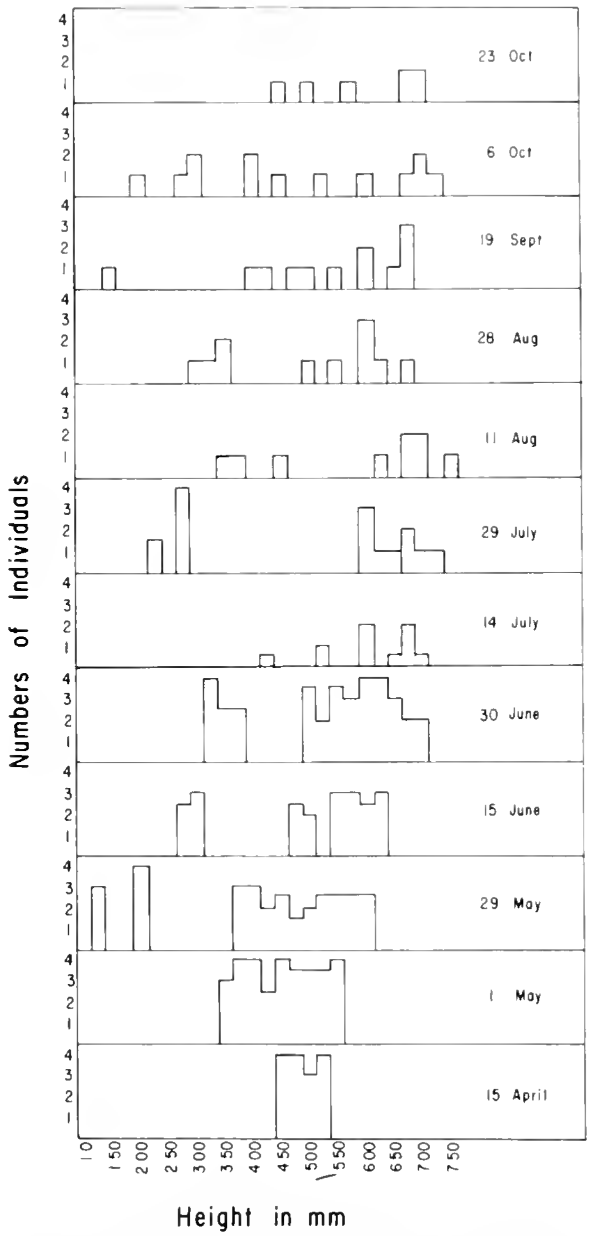
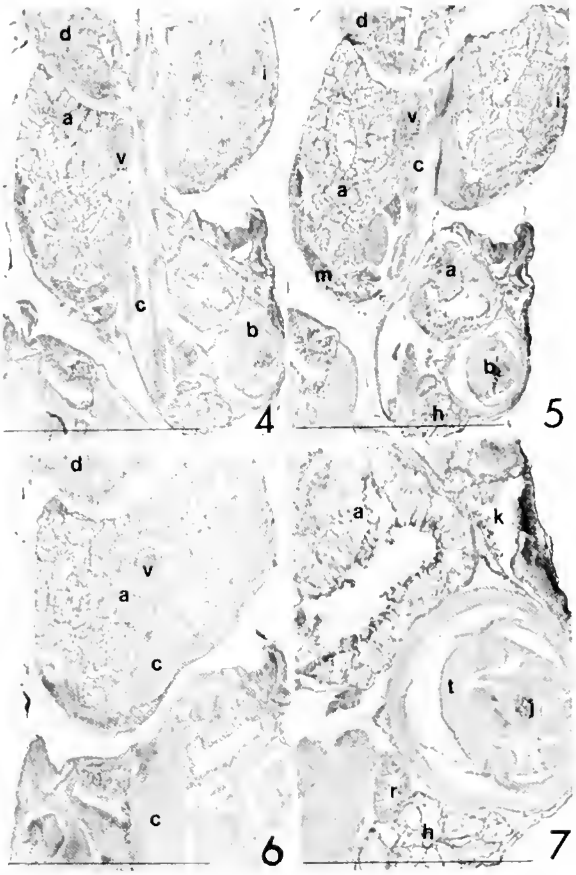


FIG. 1. Histograms showing reproductive periods of *Gulella bicolor* in the New Orleans area.

Functional Morphology

The radula (Fig. 7t) of this tiny carnivore is in keeping with those described (Solem, 1974) for molluscan carnivores in general. The individual teeth are long, slender, cutting types which have the appearance of gently curving, sharp blades. The central teeth seem to be vestigial and the number of rows of teeth varied from 48 to 52 in the specimens examined. Fig. 7 shows a serial section of the entire buccal mass and has

FIGS. 2 and 3. **2.** Ventral view of shell of *Gulella bicolor* (Hutton). **3.** Side view of shell of *Gulella bicolor* showing umbilicus.



FIGS. 4-7. *Gulella bicolor* serial sections. **4.** is almost mid-longitudinal. **5.** represents a cut 20 microns from Fig. 4 towards the ventral surface. **6.** is 20 microns further from mid-line. **7.** is an enlargement of the lower right portion of Fig. 6. **d.** digestive gland; **c.** columellar muscle; **a.** albumen gland; **v.** vas deferens; **m.** mucus gland; **r.** rectum; **h.** heart; **b.** buccal mass; **k.** kidney; **i.** intestine; **t.** radula; **j.** jaws. Fig. 4, 5, 6 bars represent 1 mm. Fig. 7 bar is 0.25 mm.

both radula (t) and "jaws" (j) showing. Jaws, as such, do not exist. However, there are in the pharynx entrance heavy, chitinous projections (15 in most *G. bicolor*) which appear to be arranged in a circle, which may help in manuevering the food material.

Aside from the radula-jaw arrangements, the alimentary canal is relatively simple. A short esophagus leads from the pharynx to the stomach. The stomach is essentially a bag, lined with tall, columnar, ciliated epithelium. It, in keeping with other carnivorous stylommatophorans, is simple. It has no accessory parts such as a gastric shield, typhlosole, or crystalline style. The stomach, in sections, shows that extracellular digestion occurs. Digestive enzymes, probably secreted by salivary glands and digestive gland as in other molluscs, are emptied into the digestive system (salivary glands into the esophagus and digestive gland into the stomach) (Mansour-Bek, 1948; Hirsch, 1915). The intestine (Figs. 4 & 5,i) seems short in contrast to that of various other species seen, extending only up into the third whorl below the apex. At that point it begins a descent and the rectum (Fig. 7r) opens within the mantle cavity on the right side of the head.

Mid-longitudinal sections reveal that the top three and one-half to four whorls are occupied mostly by the digestive gland (Fig. 4,a). It has the same basic structure as that described in many other snails (e.g., Dundee, 1957). Embedded in digestive gland at the level of the third whorl below the apex and lying in close approximation to the columella is the ovotestis (hermaphroditic gland of some authors). It is usually white to yellow and resembles a grape cluster. Each lobule is encased in squamous eipthelium and the entire structure is embedded in connec-

tive tissue. Oogenesis can be seen around the perimeter; sperm are produced in the interior. Collecting ducts in the ovotestis are lined by cuboidal, ciliated epithelium and all ultimately become one large hermaphroditic duct which proceeds anteriorly (downward). The duct bifurcates in the lower portion of the 3rd whorl below the apex. One part becomes the female system and the other the male. In most snails there is some type of fertilization chamber present near this junction but none was found in *G. bicolor*.

A large, two-part gland occupies the next two and one-half whorls. The posterior (top) portion is an albumen gland (Figs. 4, 5, 6a). It is a somewhat convoluted mass with a central, ciliated cavity. The mass, in section has an "open" appearance (Fig. 6a). The cells are either filled with secretions or appear empty (possibly due to the sectioning). The cell shape is irregular; nuclei are basal. In the whorl above the body whorl, the albumen gland joins the mucous (capsule) gland which is also large. This mucous gland is distinctly different from the albumen gland histologically. The overall appearance in section (Fig. 7m) is of a "heavy" gland containing numerous globules in the epithelial cells. The cells tend towards cuboidal and have basal nuclei. Large mucous globules are seen within the cells and in the lumen.

Ova are presumably fertilized near the bifurcation of the male-female ducts, receive albumen as they travel through the gland. While traveling through the mucous gland the fertilized ovum receives its outer coatings so that it is completed by the time it passes through the vagina and genital pore, which is located on the right side of the head of the snail. The female system also has a bursa copulatrix which is a stalked sac extending from the vagina. Sperm found in it seem to be non-oriented. It is believed (Duncan, 1975) that bursas are organs for the purpose of digesting excess foreign sperm.

Extending from the hermaphroditic duct (downward) is the prostate gland. It is composed of a ciliated columnar epithelium underlain by a thin circular muscle layer. It is in the form of follicles of columnar glandular cells and runs parallel with the albumen-mucous gland of the female. Often the prostate gland empties into the vas deferens prior to the point at which the vas passes through the body wall (that secretory duct was not found). The vas deferens (Fig. 5v), after re-entering the hemocoel enters the verge. A dart sac has been reported in some streptaxids such as *Dicartemon* (Berry, 1965), but it was not seen in *G. bicolor*.

Discussion

The carnivorous habit is found in only eight gastropod families and apparently represents convergent evolution (Solem, 1974). Most likely it evolved from a form of omnivorous activity wherein ancestors fed on dead organisms. It would seem to be only a small step to predation and/or cannibalism. One usually finds both prey and predator under the same cover in the field. As a result of its predatory activities, *Gulella bicolor* has been the object of "biological control" experiments in the past when it was introduced into Hawaii (Mead, 1961) to control the Giant African Snail, *Achatina*. The end result was that it fed upon subulinids rather than *Achatina* and, fortunately, did not destroy the endemic snail fauna.

Since this is an introduced species, and since it occurs in so few localities, little or no information on behavior is available. The fact that these snails reproduce frequently (every other month in the New Orleans area in warm weather) indicates that, given ideal conditions, the population could build up rapidly. If that were to happen, it is possible that our endemics could be substituted as food when the prey was decimated. *Gulella* as shown here, does form colonies in given areas whereas another local carnivore, *Euglandina rosea*, seems to be solitary. It is difficult to understand why these predators are so widely separated. Various possibilities come to mind. Perhaps the prey is not everywhere abundant (we do not yet know how selective these predators are). Possibly some kind of territoriality involving the coloration is exhibited although such has not been reported in molluscs. Possibly this is the "top carnivore" syndrome on a microscale.

The anatomical aspects included herein verify that this species is an advanced stylommatophoran as evidence by the reduction of accessory parts in both digestive and reproductive systems, and those systems lend support to the fact that this snail is a micropredator.

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LIVING TERRESTRIAL GASTROPODS FROM THE EASTERN CAPROCK ESCARPMENT, TEXAS

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ABSTRACT

The terrestrial gastropods of the Eastern Caprock Escarpment of the Texas Panhandle have been surveyed. Previous studies have largely been composed of flood debris specimens. A total of twelve species, including one slug, were found alive. The faunal assemblage reflects diverse zoogeographical origins.

Presently, the Eastern Caprock Escarpment of the southern Texas Panhandle supports a depauperate terrestrial gastropod fauna. More is known of the Pleistocene snails of this area (e.g. Schultz and Cheatum, 1970) than the living fauna. In order to better interpret certain samples of Holocene snail faunas (Neck, 1978; Johnson, *et al.*, 1982), a survey of the living snails of several canyon systems of the Eastern Caprock Escarpment was undertaken.

Previous Studies

As an initial step, the literature on previous land snail collections in this geographical area was surveyed. Several references were located, but most involved collections of drift debris. Henderson (1909) reported 11 small to minute species which "were found in drift debris – none actually alive and crawling about" in a canyon 24 km southeast of Amarillo. Streeker (1910) collected in the canyons of Armstrong County (southeast of Amarillo). Although he concentrated on terrestrial vertebrates, he reported four species of land snails which were "dead shells . . . found among drift material on the west bank of Salt Fork." Walker (1915) identified shells collected by E. C. Case over a large area of the south central U. S., including two Texas Panhandle localities which yielded six land species from "samples of drift". Clarke (1938) reported 11 species of land snails from "large piles of drift debris" from Palo Duro Canyon 8 km northeast of Canyon, Texas.

The above records of drift debris have been recorded as locality records in subsequent literature (e.g., Cheatum and Fullington, 1973). Wendorf (1961:109) reported that "part" of the collection recorded by Clarke (1938) was from drift; in reality only a few of the aquatic forms were recorded alive. Bequaert and Miller (1973:9) reported that four of the species which were recorded by Clarke (1938) and Henderson (1908) were alive, but no supporting evidence was provided. A reexamination of the above two

papers revealed that all specimens of terrestrial gastropods reported therein were obtained from stream drift debris.

Taylor (1960:26) utilized the species listed by Clarke (1938) as representative of the modern fauna because "there are no obvious anomalies of distribution." Pierce (1975:104-111) reported several samples of modern drift with some shells containing dried or charred flesh. Records of definitely living material known from this area include those of *Vallonia* spp. and *Rabdotus dealbatus* (Metcalf in Bequaert and Miller, 1973:63; Fullington and Pratt, 1974). Pratt (1965) reported *Stenotrema leai* in deciduous woodlands along the Canadian River in Hemphill County. Metcalf (in Franzen, 1971) found *Succinea vaginacontorta* living in Sherman Co., Texas, on the northern margins of the Texas Panhandle. Only limited information on suitable microhabitats has been provided, however.

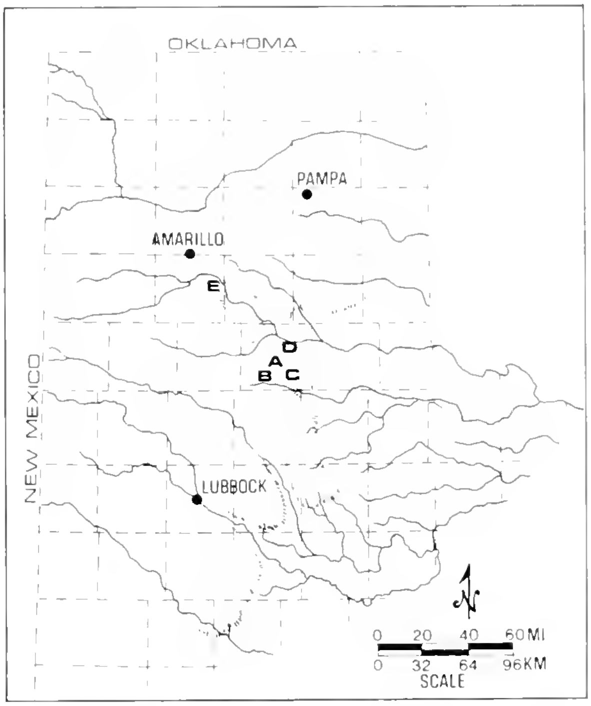

FIG. 1. Map of Texas Panhandle showing locations of sample sites. Letters refer to collection localities as listed in text.

Methods and Collecting Localities

All snails reported herein were collected alive (except shell only of *Deroceras laeve* at locality E-2 and some *Rabdotus dealbatus*). Snails were recovered from selected soil samples which had been screened through a series of nested soil sieves (#8, #16, and #30) or collected individually in random searches of suitable microhabitats. Collections were made on the following dates: 18-19 February 1976, 4 October 1977, 2 August 1978, 10 May 1979, 29-30 May 1981 and 8-9 March 1983.

Collection sites were located in canyons associated with two tributaries of the Red River (letters in locality code are located on Fig. 1). Two areas were selected in Palo Duro Canyon of the Prairie Dog Town Fork in Randall County: E-1, *Juniperus scopulorum* woodland adjacent to rural house site on Cedar Way Creek, near 35°2′N, 101°46′W; and E-2, *J. scopulorum* woodland associated with lower reaches of Spring Branch Draw on terrace of Prairie Dog Town Fork Red River, near 35°2′N, 101°43′W.

A series of collection sites were sampled within and just to the west of Caprock Canyons State Park (CCSP), Briscoe County, associated with several tributaries of the Little Red River. Site A-1 was located below a limestone pouroff in the North Prong of the Little Red River, near 34°28′N, 101°6′30″W. Site A-2 was located on a low Holocene terrace associated with the North Prong, near 34°27′55″N, 101°5′25″. Vegetation was open scrub dominated by *Prosopis glandulosa, Juniperus scopulorum, Opuntia* spp. and *Bouteloua hirsuta*. Several sites were sampled along the North Prong of the Little Red River: B-1, *Populus sargentii* thicket near western boundary of CCSP, near 34°27′N, 101°7′W; B-2, open *J. scopulorum*–*J. pinchotii* woodlands on upper terraces, snails collected from underneath rocks and leaves in juniper duff, in adjacent Boy Scout camp, near 34°27′N, 101°7′10″; B-3, same general area as B-2 on different date; and B-4, open, scrub-covered flat, near 34°27′N, 101°6′30″W. Additional sites were located on Holmes Creek. C-1 is a sandy point bar with early successional forbs just west of CCSP western boundary, near 34°25′30″N, 101°5′30″W. C-2 is scrub slope above Lake Theo dominated by *J. pinchotii*, near 34°25′N, 101°4′W. Locality C-3 is located slightly eastward of C-2 along the margins of Lake Theo. Site D-1 was a narrow, north facing header canyon of Mexican Creek next to Texas Highway 256 near 34°28′15″N, 101°5′30″W. Substantial soil and *Quercus havardii* leaf litter

had accumulated on Triassic Upper Dockum (Trujillo) Sandstone.

Discussion of Species Recovered

Vallonia parvula Sterki, 1893, was recovered from five localities in narrow canyons with arborescent vegetation. Snails were found under rocks, logs and in deep leaf litter. This small species is found living from Ontario to South Dakota southward to the Texas Panhandle with an apparently introduced population in Florida (Pilsbry, 1948:1028). *V. parvula* is found in woodlands that are most often associated with a river or lake (Baker, 1939:119; Leonard, 1959;189), although it is adapted to relatively xeric climatic conditions (Leonard, 1943; Hibbard and Taylor, 1960). Fullington and Pratt (1974:29) reported *V. parvula* from deep leaf litter of *Populus sargentii* along Palo Duro Creek.

Vallonia gracilicosta Reinhardt, 1883, is somewhat less common than *V. parvula* and is significantly larger. All three localities with *V. gracilicosta* also supported populations of *V. parvula*. *V. gracilicosta* has been recorded from Montana and North Dakota south to New Mexico (Pilsbry, 1948:1029). Published habitat descriptions encompass prairie groves and riparian woodlands (Baker, 1929; Woodbury, 1929; Shimek, 1930) where snails are found in moist humus of protected woodland sites (Taylor, 1960). Metcalf (in Bequaert and Miller, 1973:63) found *V. gracilicosta* living in Gray County approximately 100 kilometers NNE of Caprock Canyons State Park. Fullington (1979) found living specimens in Guadalupe Mountains National Park, Culberson Co., Texas.

Pupoides albilabris (C. B. Adams, 1841) was found only in a total of four sample sites but occurred in some of the more exposed sites. This wideranging species is known from the Dakotas to Arizona eastward to the Atlantic coastal areas and southward to Mexico and the Greater Antilles (Pilsbry, 1948:923). *P. albilabris* is found under rocks and downed wood in deciduous woodlands, savannahs and prairies (pers. observ.).

Gastrocopta procera (Gould, 1840) was found at five sampling locations encompassing all canyons surveyed. *G. procera* inhabits a large area of the southern United States from Maryland to Kansas and Arizona (Pilsbry, 1948:907). *G. procera* occurs in many of the same microhabitats

TABLE 1. Occurrence of living terrestrial gastropods at various sample sites in Texas Panhandle. See text for location and description of sample sites. X = presence of species.

	Localities												
	A-1	A-2	B-1	B-2	B-3	B-4	C-1	C-2	C-3	D-1	E-1	E-2	Total
Vallonia parvula				X	X		X				X	X	5
Vallonia gracilicosta				X							X	X	3
Pupoides albilabris			X	X	X		X						4
Gastrocopta procera	X				X		X				X	X	5
Gastrocopta pellucida				X	X		X	X		X	X	X	7
Gastrocopta cristata			X	X	X		X	X			X	X	7
Gastrocopta armifera					X						X	X	3
Succinea cf. avara		X											1
Deroceras laeve									X			X	2
Helicodiscus inermis				X	X					X		X	4
Helicodiscus parallelus				X	X							X	3
Rabdotus dealbatus						X							1
# of species (12)	1	1	2	7	8	1	5	2	1	2	6	9	--

as *P. albilabris*, but requires slightly more moisture i.e., tree cover (pers. observ.).

Gastrocopta pellucida hordeacella (Pilsbry, 1890) was found at six localities in the study. *G. p. hordeacella* ranges from New Jersey to Florida to Baja California (Pilsbry, 1948:914). This small species is often associated with *G. procera* but is more drought tolerant and is often associated with grass roots (Fullington and Pratt, 1974:17).

Gastrocopta cristata (Pilsbry and Vanatta, 1900) was found in more sites than any other species recovered in this study. This species occurs from Arizona to central Oklahoma and Texas (Pilsbry, 1948:913). Habitats are generally calcareous but include both grasslands and woodlands in both upland and bottomland areas (Fullington and Pratt, 1974:14).

Gastrocopta armifera (Say, 1821) was found in only three sample sites. Geographical range of this species includes an area bounded by Quebec, Florida, Alberta and New Mexico (Pilsbry, 1948:875). Leonard (1959:170) states that *G. armifera* "occurs in a wide variety of habitats." A large number of county records in central, western and north central Texas were listed by Fullington and Pratt (1974:10-11), but many of these are probably drift debris shells of Pleistocene origin. Hubricht (1972) reviewed the *armifera* complex and recognized five species; however, all specimens collected during this study appear to fall within nominate *armifera*. Recovered living specimens were found under leaf litter in canyon and floodplain woodlands.

Succinea cf. *avara*, Say, 1824 (*sensu* Franzen), was found only at one locality under old juniper wood (in contact with soil) which was concentrated into small piles during brush-clearing operations during the late 1950's. Shell color is a dilute orange-brown while the body was a featureless grayish-cream. Living mature snails were most likely to be found underneath trunk bases than under a simple branch. Smaller individuals were usually found immediately between wood and soil whereas larger specimens were found on semi-exposed portions of wood.

S. avara is a very troublesome name. Type specimens are shells with no soft parts, a necessity for proper identification of members of the family Succineidae. Franzen (1982) utilizes *S. avara* as a name for succineids from a large geographical area including at least southwestern Kansas. Habitat associations of *S. avara* (*sensu* Franzen, 1982) are varied as are localities reported by Pilsbry (1948: III, 2: 839). The habitat heterogeneity and "rather wide variation" in genitalia (Pilsbry, 1948: III, 2: 840) indicate the likelihood of a number of unrecognized (possibly undescribed) species, especially in the southern United States. Pending an extensive anatomical investigation by a future brave (masochistic?) systematist, the best solution seems to be to refer to these populations as *Succinea* cf. *avara*.

Succinea vaginacontorta Lee, 1951, has been reported from Sherman Co., Texas, on the northern edge of the Texas Pandhandle (Metcalf, in Franzen, 1971) and in an urban landfill in the southern Panhandle (Neck, unpub.). *S. vaginacontorta* is found in the High Plains of the central United States from Texas to North Dakota (Leonard, 1959; Franzen, 1971). Typical of xeric sites, *S. vaginacontorta* appears to be a regional representation of what many workers have called *Succinea grosvenori* Lea, 1864, (Shimek, 1935; Pilsbry, 1948:3(2):821; Hubricht, 1963).

Deroceras laeve (Müller, 1774) is a limacid slug found living at one site (C-3) and represented by a single internal shell at another site (E-2). Slug populations referable to *D. laeve* have been reported from the Arctic to Central America on both sides of the Rocky Mountains (Pilsbry, 1948:540-541). The living slugs were found above the water level of Lake Theo during a low water period. In comparison to specimens from central Texas, the slugs were rather slim and long and of a definite black color. These slugs are referred to *laeve* because they do not possess the greatly thickened shell of *aenigma* Leonard, 1950, which was widespread in the Great Plains during the Pleistocene. Shells of the Panhandle slugs are thinner than shells of central Texas slugs. However, much variation in shell thickness has been observed among *D. laeve* populations (pers. observ.). During the Late Pleistocene the Great Plains apparently supported varied genetic stocks of *D. laeve* east of the Rocky Mountains. During the Holocene, or even earlier, a stock with a more gracile shell was selected preferentially.

Helicodiscus inermis Baker, 1929, is a minute

species which was found at only three collecting sites which were among the most protected of the areas sampled. Originally, *inermis* was described as a subspecies of *H. singleyanus* (Pilsbry, 1890) which has generally been considered to range from New Jersey to Florida westward to Iowa and Arizona (Pilsbry, 1948: 636). However, recent work on the smaller species of *Helicodiscus* by Hubricht (1962, 1965, 1968, 1975) indicates that *H. singleyanus* may be restricted to central Texas, New Mexico and Arizona (although specimens from the central Atlantic coastal region also appear to be true *singleyanus*). A detailed study of populations of the subgenus *Hebetodiscus* is needed to separate genetic and ecophenotypic variation. *H. inermis* ranges from New Jersey to Florida westward to Texas and Oklahoma. Characters which place the Caprock populations in *H. inermis* are the smaller shell size and relatively tightly coiled shell (compared to *H. singleyanus*). A typical shell has a diameter of 2.2 mm with a height of 0.95 mm for a shell with 3.6 whorls. This species is found in a variety of microhabitats in leaf litter or under rocks and downed wood.

Helicodiscus parallelus (Say, 1817) was found only at the more mesic sampling stations. This species occurs over most of the eastern United States as far west as the central Great Plains (Pilsbry, 1948:625), where it is found in relatively mesic deciduous woodlands. In comparison to shells from eastern Texas, the Pandhandle *H. parallelus* are slightly more domed-shaped with a thinner, less yellowish shell. Apertures are too narrow to be referred to *shimeki* Pilsbry, 1890. Shells of *H. parallelus* from the Caprock area of Texas have broad whorls (which narrow the umbilicus) and, the aperture is taller than wide. Raised threads are present but very faint on the protoconch with transition to the coarser threads on subsequent whorls being gradual. Pierce (1975) reported that *H. parallelus* was replaced by *H. eigenmanni* in the early part of the Altithermal in the High Plains area of Texas. However, *H. parallelus* has survived in the CCSP area where studies of Holocene land snails (Johnson, *et al.*, 1982) revealed a few *H. parallelus* in the upper soil layers but no *H. eigenmanni*. The true taxonomic relationship between these two taxa is still unclear (see analysis of Oklahoma specimens by Branson, 1963).

Rabdotus dealbatus (Say, 1821) was represented by one living specimen collected in an open scrub savannah habitat during a rainstorm. *R. dealbatus* occurs from northern Mexico to southern Illinois and east to Mississippi (Fullington and Pratt, 1974:16). *R. dealbatus* is generally found in woodland habitats on stream terraces, although it is found in prairie areas east of the range of *Rabdotus mooreanus* (see Pratt, 1974, for differentiation of these two forms). The shell of the living snail (height – 21.7 mm, diameter – 12.7; 6.0 whorls) is somewhat thinner and less ridged than a sample of dead shells found on the surface of a xeric slope above Holmes Creek. Age of these old shells is unknown but widespread bulldozing of juniper and mesquite in the late 1950's probably devastated the remaining *R. dealbatus* habitat, i.e. open woodland. However, the presence of isolated, single shells found along and downslope from the Ogallala scarp woodland in the western portions of Caprock Canyons State Park indicates the former existence of more abundant populations at some time during the past (perhaps prior to the historic period). None of the shells is sufficiently ridged to be referred to *ragsdalei* Pilsbry, 1890.

Discussion

The presently known land snail fauna of the Eastern Caprock Escarpment of Texas consists of twelve species of diverse zoogeographical origins. Three species (*Gastrocopta armifera*, *Helicodiscus inermis* and *Helicodiscus parallelus*) are eastern species which are near or at the western limit of their geographical ranges. An additional three species (*Pupoides albilabris*, *Gastrocopta procera* and *Gastrocopta pellucida hordeacella*) are basically eastern species but occur farther west than the present study area; the latter species has a southern range affinity also. Three species (*Vallonia parvula*, *Vallonia gracilicosta* and *Succinea* cf. *avara*) have their affinities to the north and northwest. Single species each have their affinities to the southwest (*Gastrocopta cristata*) and the south (*Rabdotus dealbatus*). One species (*Deroceras laeve*) has a very widespread range in all directions from the study area.

Certainly, additional living species may be found in the Texas Panhandle, but the number to be expected is very low. Examination of drift

debris in these same areas revealed no additional species with fresh shells.

The current fauna of the study area is a very depauperate fraction of a richer fauna which existed along the Eastern Caprock Escarpment up until about 9000 years B. P. (Schulz and Cheatum, 1970; Pierce, 1975; Johnson, *et al.*, 1982). Twenty-two species are known from the Caprock Canyons State Park area at 10,000 B. P. (Johnson, *et al.*, 1982). Additional species were present in the Panhandle portion of Texas at that time (Pierce, 1975). With the exception of *R. dealbatus*, *S.* cf. *avara*, and *D. laeve*, all remaining species are minute in size. Species of small-sized individuals can exist in smaller microhabitats than can the larger species. Various *Vallonia* can survive a series of inclement seasons in small areas with rock, downed wood or deep leaf litter. Larger species, e.g. *R. dealbatus*, live in a more coarse-grained environment, i.e. require a larger area of suitable habitat to survive.

Almost all living snails recovered in this study were found in wooded areas. More species, including the more mesic-adapted species, were found in relatively heavily wooded areas with closed canopies and deep leaf litter. Sites with less wooded cover and only surficial litter accumulations supported fewer numbers of species. *D. laeve* was found both along a lakeshore and in well-drained woodland soil with deep leaf litter. No prairie sites, either native or reclaimed, were available for sampling during this study. Should suitable prairie sites become available, surveys of the snail fauna will be pursued.

Modern human utilization of the study area has involved diverse, indirect impacts. Logging for larger specimens of Rocky Mountain juniper, *Juniperus scopulorum*, and hackberry, *Celtis occidentalis*, reduced suitable microhabitats in canyon slope and stream terrace areas by increasing solar insolation and erosion plus decreasing accrual rates of leaf litter. Grazing activity has decreased grass cover and increased brush cover and soil erosion. Subsequently, extensive areas were bulldozed to reduce brush cover. Farming activities definitely disrupted the prairie communities but the level of snail presence in these habitats under natural conditions is still unknown.

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RANGE EXTENSION OF THE FRESHWATER MUSSEL, *PLECTOMERUS DOMBEYANUS*, INTO THE TENNESSEE RIVER, KENTUCKY

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ABSTRACT

The naiad mollusk, Plectomerus dombeyanus *(Valenciennes, 1827), from the Mississippi and Gulf of Mexico coastal rivers, is reported for the first time in the Tennessee River. Apparently,* P. dombeyanus *has never been reported from the Ohio River System. Of the two live specimens found on August 10, 1981, in Kentucky Lake at Tennessee River mile 44.5, one was 5 years old, and the other was a 7 year old gravid female with fully developed glochidia indicating successful reproduction is probably occurring. The importance of naiad surveys in this region is discussed.*

The discovery of two, live specimens of *Plectomerus dombeyanus* (Valenciennes, 1827) in Kentucky Lake at Tennessee River mile 44.5 (36°44′12″N, 88°06′05″W), Trigg County, Kentucky, on August 10, 1981, extends the known range of this species into the Tennessee River System (Pharris *et al.*, 1982). On that day a collecting team consisting of two SCUBA divers, Garry L. Pharris and Carol C. Chandler, accompanied by James B. Sickel, John M. Bates and Sally D. Dennis was conducting a survey of the freshwater mussels in the vicinity of the Hancock Biological Station of Murray State University. On one dive covering a 20 m² area, Pharris brought up the two specimens along with ten *Quadrula quadrula* (Rafinesque, 1820), six *Amblema plicata* (Say, 1817), two *Megalonaias nervosa* (Rafinesque, 1820), three *Fusconaia*

flava (Rafinesque, 1820), three live and five shells of *Obliquaria reflexa* Rafinesque, 1820, and two live and three shells of *Quadrula nodulata* (Rafinesque, 1820). Sally Dennis and John Bates provided the initial identification which was later confirmed by David H. Stansbery.

The larger of the two specimens of *P. dombeyanus* was a gravid female with fully developed, unhatched glochidia filling the marsupial water tubes of all four demibranchs. The smaller specimen was not gravid, but its sex was not determined. The presence of a gravid female and another individual of different age is an indication that successful reproduction is occurring in Kentucky Lake. Table 1 summarizes the measurements of the two specimens.

The two specimens were located within a few meters of each other. An area of 10 m² had been searched by Pharris using a 1 m² aluminum frame quadrat sampler. The other 10 m² had been searched by Chandler. The habitat was the crest of a submerged river bank, or levee, adjacent and parallel to the old river channel. The substratum was a firm clay with some gravel covered by a thin, less than 2 cm, layer of silt which was easily swept away with water movements created by a diver. The site was 700 m from the eastern lake shore and at a depth of 6 m. Being adjacent to the river channel, the site had a detectible, although slight, current greater than that of typical lake habitats. The species composition of the associated naiads also indicated the more riverine character of the habitat within the river-lake system of Kentucky Lake.

The previous range of *Plectomerus dombeyanus* as given by Simpson (1914) was the Gulf coastal rivers from the Alabama River west to eastern Texas and north in the Mississippi River System to northwest Tennessee. Call (1895) reported *P. dombeyanus* in the St. Francis River in eastern Arkansas, and Johnson (1980) excluded it from the Mississippian and Ohioan Regions above the confluence of the Mississippi and Ohio Rivers. Ortmann (1926) reported it from the North Fork Obion River, Union City, Tennessee, a tributary of the Mississippi River in western Tennessee. Van der Schalie (1939a) reported this species from the Tombigbee River but not from the other tributaries of the Alabama River System (van der Schalie, 1938), and Hanley (1981) presented evidence from Indian shell mounds that *P. dombeyanus* has become established in the upper Tombigbee only within the last 300 years. The headwaters of the Tombigbee in northeast Mississippi come within 30 km of the Tennessee River, and those of the Obion River reach to within 15 km of tributaries of the Tennessee. However, the Obion has been channelized for much of its length, and it is unknown whether or not *P. dombeyanus* survives there. Extensive surveys of the Tennessee River naiads by Ortmann (1918, 1924, 1925), Ellis (in: van der Schalie, 1939b), Scruggs (1960), Isom (1969), Williams (1969), and Yokley (1972) had failed to reveal the presence of *P. dombeyanus*. Apparently, *P. dombeyanus* has but recently established a population in the Tennessee River.

Although the Obion and Tombigbee are the nearest rivers to the Tennessee, by land, which historically possessed *P. dombeyanus*, the nearest by water which is known to have *P. dombeyanus* is the St. Francis River in Arkansas some 580 km distance, over 500 km of which is the lower Mississippi River. If *P. dombeyanus* does occur in the tributaries or oxbows of the Mississippi River in the vicinity of the Obion, it is still a distance of 285 km to the Tennessee River. This raises the proverbial question, "How did *Plectomerus dombeyanus* get into Kentucky Lake?" Obviously, only suggestions may be offered.

Ortmann (1913) and van der Schalie (1938, 1945) supported the idea of stream confluence, or capture, as playing the major role in determining present distributions of North American freshwater mussels. Clearly, there has not been

TABLE 1. Measurements of two species of *Plectomerus dombeyanus* from Kentucky Lake.

Shell Length (mm)	Shell Height (mm)	Shell Width (mm)	Total Wet Weight (g)	Shell Weight (g)	Age (yrs)
59.8	30.7	16.7	21.6	19.9	5
80.1	48.9	29.8	77.9	64.8	7

a recent connection between the Obion or Tombigbee and the Tennessee River, although there will be one with the Tombigbee in a few years when the Tennessee-Tombigbee Waterway opens.

There is no evidence for a gradual population extension up the Mississippi and Ohio Rivers into the Tennessee, and the main stem of the Mississippi below its confluence with the Missouri is noted for its depauperate mussel fauna (van der Schalie and van der Schalie, 1950). It has even been considered a barrier to some species (Stansbery, 1973). The chance occurrence of fish hosts carrying glochidia from the lower Mississippi tributaries, where *P. dombeyanus* occurs, up the Mississippi and Ohio Rivers into the Tennessee over such a great distance seems unlikely but should not be overlooked. At least two species of fish which inhabit Gulf coastal rivers are known to migrate upstream into the Tennessee River. The American eel, *Anguilla rostrata*, and a striped mullet (report unconfirmed), *Mugil cephalus*, have been collected from Kentucky Lake. However, since *P. dombeyanus* females release glochidia during summer months when water temperatures are high and larval development is probably rapid, the likelyhood of a glochidial infection lasting a sufficient length of time for the fish host to swim upstream for almost 600 km is remote.

This leaves two other possible origins for *P. dombeyanus* in Kentucky Lake: overland transport (or some artificial means by water) and a remnant population. The idea of a remnant population was suggested by Dr. David Stansbery. Even with the many surveys of mussels in the Tennessee River, it is possible that this species has been overlooked. Since "the species is a mud-loving one, and delights in sluggishly flowing water" (Call, 1895) and might not have been present in shoals where the predominant Tennessee River fauna was located, *P. dombeyanus* may have been overlooked. With the construction of Kentucky Dam in 1945, suitable habitat for *P. dombeyanus* has been increased greatly and may have stimulated a population increase.

Clearly, many opportunities exist for overland or artificial transport. This category should also include transport by barge or boat over barriers to natural dispersal such as dams or rivers lacking suitable habitats. Over the past decade, increased commercial harvesting of mussels by divers has provided a new method for accidental or intentional transport of mussels from one drainage basin to another: the diver's bag and equipment. Juvenile mussels with byssal threads could become entangled in diving gear on one day and carried to another river the next. Larger mussels might be placed in a bag underwater in one river system and culled from the catch in another. Without overlooking the complexity of the mussel life cycle and the importance of suitable habitat and fish hosts for the establishment of a reproducing population, the possibility of overland transport cannot be ruled out. This may be more likely today because the system of 'river-lake' reservoirs of the Tennessee River and the mixing of fish fauna through intentional fish introductions and other fishing activities might create a suitable environment for mussel species not native to the system.

This discovery of *Plectomerus dombeyanus* in Kentucky Lake emphasized the need for continued monitoring of aquatic systems. It also points out the dynamic nature of aquatic fauna – even the naiad mollusks which are more restricted in their abilities to disperse than perhaps any other aquatic animal. When the Tennessee and Tombigbee Rivers are connected, extensive faunal changes can be expected. A record of this change would be most interesting and useful to present and future biologists. More intensive surveys of both river systems should be conducted to determine the existing similarities in the faunas prior to the opening of the waterway. The recent discovery of *P. dombeyanus* in the Tennessee River will avoid mistakenly attributing its introduction to the Tennessee Tombigbee connection.

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ARCHITEA A. COSTA, NOT AN ARCHITECTONICID BUT A POMATIASID (GASTROPODA: PROSOBRANCHIA)

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Achille Costa (1869) introduced the generic name *Architea* with the sole species *A. catenulata*, A. Costa, as monotype, based on a single specimen from the Island of Capri in the Gulf of Naples, giving the following description and placing the taxon in the gastropod family Solariidae (now Architectonicidae):

(Generic): *Testa turbinata, parum elevata, infra late et profunde umbilicata; apertura rotundata, periostomate continuo, simplici. Operculum corneum, pellucidum, spirale, extus plano, levi, intus spria ad centrum parum prominula.*

(Specific): *Testa solida, anfractibus, rotundatis, longitudinaliter subtiliter et crebre subcatenulato-costulatis, transversim obsolete rugosis. Diam. mill. 13; alt. mill. 9; diam. operc. mill. 6.*

This newly described species and genus was listed in the reviewing and abstracting periodicals (Gentiluomo, 1870: 54; von Martens, 1870:

136). Subsequent workers similarly have included the genus and species in the family, allotting the name *Architea*, variously spelled, to generic or subgeneric rank. Thus, Monterosato (1875:5 and 36) changed the spelling to *Archytaea* or *Architaea* and noted that the monotypic genus shared features with other gastropod genera (*Mölleria*, *Trochus*, and *Solarium*). Kobelt (1887:217) used the spelling *Archytea* and Fischer (1885:714), using the spelling *Archytaea* assigned it as a questionable subgenus of *Solarium* (now *Architectonica*). Thiele (1929:184), Wenz (1938:666) and Pchelintsev and Korobkov *in* Orlov (1960:137) considered *Architea* as a subgenus grouping under *Torinia* (now *Heliacus*).

In the primary literature on the fauna of the Mediterranean Sea or its divisions, *Architea catenulata* has consistently been included, generally repeating the description in the original Latin or in vulgate translations (Kobelt, 1887:217; Carus, 1889-1893:348; Parenzan, 1970:93; Nordsieck, 1968:64). In his monograph of *Torinia* (now *Heliacus*) Bayer (1948:10) considered *A. catenulata* as a species without subgeneric categorization and therefore synonymizing *Architea* under *Torinia* (now *Heliacus*).

In our own ongoing critical study of the Architectonicidae of the Atlantic Ocean including the Mediterranean Sea, we reexamined the original figures of Costa which revealed some rather unusual features inconsistent with architectonicid characteristics, namely a perfectly rounded aperture, non adanate to the last whorl, and similarly tubular, perfectly rounded earlier whorls and a concentrically multi-spiral operculum. Such an operculum is not characteristic of *Heliacus* to which *Architea* had been almost universally assigned though another representative of the family, phylogenetically removed from *Heliacus*, namely *Philippia krebsi* (Mörch), has such an operculum. Also, Costa's figures show a specimen lacking an umbilical wall which is usually very distinctive in true architeconicids.

Further suspicion is also raised by the fact that the species is known only by a single specimen despite the many years of active collecting and research by the workers of the famed Zoological Laboratory in Naples.

Some of the characters of *Architea* are suggestive of a terrestrial prosobranch family. Confusion of an architectonicid with presumed land snails has a precedent in the naming of *Teretropoma* by Rochebrune (1881:110).

In further reviewing the Italian literature we came upon a hitherto overlooked footnote appended to the synopsis of the malacofauna of the Gulf of Naples by Bellini (1929:83) which confirmed our suspicions; he showed that the unique holotype of *Architea catenulata* Costa housed in the Geological Museum at Naples is a Madagascarian representative of the terrestrial prosobranch family Pomatiasidae. He placed it in *Cyclostoma* but it is more probably a representative of *Tropidophora* (Boss, 1982:983; Wenz, 1938:534). We herein quote Bellini's (1929:83) note in full and append a translation: "L'unico individuo di questa supposta specie venne dal COSTA depositato nella collezione del R. Museo Zoologico di Napoli; ma l'*habitat* (Capri) e la sua determinazione dànno luogo a molti dubbi, essendo la conchiglia rassomigliantissima a quella di alcune *Cyclostoma* terrestri del Modagascar. Si può quinidi pensare che debba trattarsi di una forma esotica non marina trovata casualmente nel nostro mare. Il fatto di rinvenire individui morti di specie di altri climi in località dove prima mai si erano raccolti, non è sufficiente per accettarne l'esistenza nelle fauna locali. Occorre che gli individui sieno stati osservati allo stato vivente e, per maggior garenzia, anche più di una volta."

(English translation) The only specimen of this postulated species came from those Costa deposited in the Royal Geological Museum of Naples; but its habitat (Capri) and its determination are doubtful, since the shell is extremely similar to some land *Cyclostoma* from Madagascar. It is probable that this must be an exotic land species found by chance in our seas. The finding of dead specimens, belonging to a species from other climates, where they have never been collected before is not sufficient to ascertain their existence in the local fauna. It is necessary for the specimens to be observed while still living and, for greater certainty on more than one occasion.

This observation of Bellini (1929) is in accord with, and probably takes its inspiration from, another much earlier footnote buried in the

Italian literature, namely Monterosato's (1873: 14) remark which is an addendum to p. 45 of his earlier *Notizie* (1872) and which makes the same suggestion.

Thus, the generic name *Architea* and its variant spellings as well as its sole species is removed from the Architectonicidae and placed in the pomatiasids where it is probably a synonym of one of the well-known Madagascar genera.

We thank Mr. Montano Nissotti, Harvard '85, for correcting and confirming our translation.

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REVIEW

The Freshwater Snails of Connecticut by Eileen H. Jokinen. 1983. Bull. 109, State Geological and Natural History Survey of Connecticut, vii + 83 pp., 35 figs. For a copy, send $5.00 to the Survey, Room 555, Dept. Environmental Protection, State Office Bldg., Hartford, CT 06106.

This compact guide to the freshwater gastropods of Connecticut fully covers the 26 pulmonate and nine prosobranch species found in the rivers and ponds of this New England state. Keys, including both shell and soft-part anatomy, clear line drawings, and brief, but adequate, descriptions assure easy identification of these 35 species. The introductory material covers factors affecting distributions and abundance, instructions on investigating and collecting freshwater mollusks, and how to preserve and dissect specimens.

The booklet presents distributional maps for each species and an appendix giving the water conditions and species present in about 150 ponds and lakes and the streams running into three major rivers. A very large and useful bibliography will allow future students to delve into the still-existing mysteries of the Connecticut freshwater snails. A re-study of the *Physa* (or *Physella*) species, including ones possibly introduced from Europe, may be in order.

This extensive survey puts on record the physical and biological conditions of the freshwater bodies of the State, and records the mollusk inhabitants which are so useful as ecological indicators.

—*R. Tucker Abbott,*
American Malacologists, Inc.

DISPERSAL MOVEMENTS OF FOUR SPECIES OF PULMONATE AND OPERCULATE SNAILS IN DOUGLAS LAKE, MICHIGAN

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ABSTRACT

Various species of freshwater operculate and pulmonate snails show marked differences in rate of dispersion, total distance moved and direction of movement. Field experiments conducted between July and August 1982 showed that forty-eight hours after release, Goniobasis livescens *traveled the greatest distance and had the largest percentage of snails that moved a minimum of 1 m. In contrast,* Helisoma anceps *dispersed the least with only 5% moving past one meter during the same time. The longest distance moved by any* H. anceps *was 1.6 m.* Physa integra *and* Lymnaea catascopium *were similar in the rate of movement, but differed in the total distance traveled. Finally, variations in direction of movement were observed among the four species. Both* P. integra *and* L. catascopium *moved up the slope (toward shore); however,* G. livescens *preferred to move away from shore to deeper water;* H. anceps *appeared to show no directional movement.*

Snails represent an important component of the biota of most aquatic habitats. As herbivores, they graze on many species of algae. They also serve as prey for several species of vertebrates. Finally, aquatic gastropods serve as intermediate hosts for a group of parasitic flatworms known as digenetic trematodes.

Relatively little is known about the population fluctuations of either pulmonate or operculate snails. Even less is known about the rates and direction of dispersal movements, especially of operculates. Two workers have indicated that some species of pulmonates undergo seasonal migration. Cheatum (1934) reported that snails go to deeper water during the winter months and return to shallower water in the spring. Adults of *Physa integra* were shown to follow such a pattern (Clampitt, 1974 and 1975); however, he also reported in the latter study that juveniles of the same species demonstrate a different pattern. They appear to move away from shore (into deeper water) during the summer.

Other investigators have found that some species of pulmonates do not follow seasonal migratory patterns as outlined by Cheatum (1934). For example, *Lymnaea catascopium* does not go to deeper water during the winter months (Wall, 1977). Instead, there are random movements within the population. Clampitt (1975) also indicated that two species of planorbid snails, *Helisoma anceps* and *H. campanulata*, showed little if any movements for weeks or months at a time.

This study was initiated to compare and contrast the short-term dispersal movements (rate and direction) of four species of aquatic snails.

Materials and Methods

Field experiments were conducted on South Fishtail Bay of Douglas Lake (Cheboygan Co., Michigan) from July to August 1982. The specific area was selected because it was protected from wave action that results from strong westerly winds. The substratum, composed of sand with a top layer of organic material, gradually sloped (approximately 15°) downward away from shore.

Aquatic snails representing four families were selected for this study: *Lymnaea catascopium* (Say) (Lymnaeidae), *Physa integra* Haldeman (Physidae), *Helisoma anceps* (Menke) (Planorbidae), and *Goniobasis livescens* (Menke) (Pleuroceridae). All represent pulmonate snails, except the latter species which is in operculate.

Distances that snails traveled from a point of release were determined using a ten-meter grid that was similar in design and location to the

one used by Clampitt, 1974. However, the grid was modified by having additional stakes radiating two meters from the center to enhance stability and facilitate counting. With the aid of SCUBA, the middle of the grid was secured at a depth of 4.5 meters (approximately 32 meters from shore).

For each of the four experiments, a minimum of 400 snails was collected from Douglas Lake. Snails representing each species were color-coded with "Tech-Pen" (Mark-Tex Corporation) using a small paint brush. This facilitated locating the snails, especially in turbid water.

In a circle with a radius of approximately 12 cm, snails were placed directly on the substrate in the middle of the grid. After 10, 24, and 48 hours, the location and number of the released snails were observed. Dead snails were removed from the study site after their location had been recorded. Distances that the snails traveled were grouped as 1m, 2m, 3m, 4m, 5m. Data were recorded under water on a plastic slate. A pre-calibrated line of 10m was used to measure the distances of snails outside the 5m radius. This was also utilized as a "swing line" to mark off each distance to determine the specific area of dispersal for each snail. After each count, the water temperature was recorded.

All work under water was facilitated by using buoyancy compensators. Observers could then assume an inverted position approximately 60 cm from the bottom without disturbing the substratum or the snails.

Results

Data obtained from this study show that snails do show differences in rate and direction of movement as well as in total distance moved after a prescribed time. Of the four species, *Goniobasis livescens* moved the greatest distance (9.5 m) after 48 hours from the point of release (Fig. 1). *Physa integra* traveled less than 8 meters during the same time. The remaining two species of snails, *Lymnaea catascopium* and *Helisoma anceps* dispersed a considerable shorter distance of 3.6 and 1.6 m, respectively. Members of all four species moved the greatest distance during the first ten hours following release. In fact, little distance was traveled after the initial 24-hour period.

Figure 2 illustrates the percentage of snails that moved one meter or more after 10, 24, and 48 hours. After 10 hours, 83% of *G. livescens* had moved at least one meter from the point of release. At the other extreme, *H. anceps* had little if any movement during the first 24 hours. After 48 hours, only 5% of the planorbid snails had dispersed one meter or more. *Lymnaea catascopium* and *P. integra* showed rates of movement that were intermediate to those of *G. livescens* and *H. anceps*. However, after 48 hours, approximately half of the snails had passed the one meter mark.

Three species of gastropods showed a dispersion in a definite direction. There was a concen-

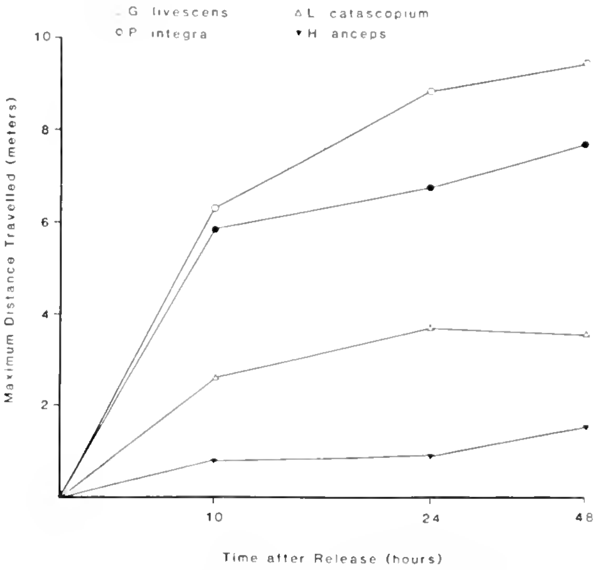

FIG. 1. Maximum distance traveled by four species of snails, 10, 24, and 48 hours after release.

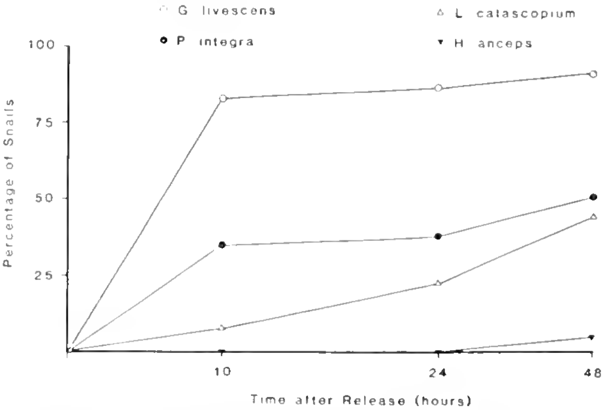

FIG. 2. Percentage of snails that moved at least one meter 10, 24, and 48 hours after release.

tration of *G. livescens* down the slope (lower left quadrant) during each of the observation periods. *Lymnaea catascopium* and *P. integra* showed movements in the opposite direction, compared with *G. livescens* (up the slope, toward shore). Consistently, between 24-48 hours, a greater percentage of snails past one meter from the release point had moved toward shore. Because *H. anceps* traveled slowly, it was impossible to determine significant movements in any specific direction. After 48 hours, only 3% had moved past one meter; most were in the upper portion of the grid.

The percentage of recovered living snails after the last observation (48 hours) for *Physa integra* and *Helisoma anceps* were 72% and 76%, respectively in comparison to *Lymnaea catascopium* and *Goniobasis livescens* which were 86% and 87%, respectively.

Discussion

The habitat requirements of various species of operculate and pulmonate snails differ. Therefore, differences in snail distribution, rate of movement, direction of dispersion and distances traveled over time should be expected. Previous workers (Clampitt, 1973, 1974, 1975 and Wall, 1977) have suggested some factors that may influence the above parameters. These factors include substratum preference, gravity, light intensity, availability of food and direction of subsurface water currents.

Clampitt (1975) observed that *Physa integra* dispersed rapidly while a planorbid, *Helisoma anceps*, may move very little for weeks or even for months at a time. Data from the present study support his findings and indicate that a much greater percent of *P. integra* moved further than one meter after 10 hours, than did *H. anceps*. However, an operculate snail, *Goniobasis liveseens* moved the fastest; *Lymnaea catascopium* was intermediate in the rate of movement between the physid and planorbid.

Using the data on subsurface currents in Douglas Lake, plotted by Gannon and Brubaker (1969), Clampitt (1974) studied dispersal movements of *P. integra* in South Fishtail Bay. He found that this species of physid had a tendency to travel against the current. Data obtained during the present study conducted in the same area of Douglas Lake during the summer of 1982 do not support his findings. Snails of the same species moved from the deeper water toward shore irrespective of the direction of water flow. Either *P. integra* vary their dispersal movements independently of current direction, or other variations in the subcurrent direction of flow in South Fishtail Bay have occurred since Gannon and Brubaker reported their findings.

Data from our study does confirm the findings of Clampitt (1974) and Wall (1977) who found that over a longer period of time, snails will migrate from deeper water toward the shore during the summer months. Wall (1977), working with *Lymnaea catascopium* over a three-year period, found this pulmonate to consistently move up the slope, toward shore.

Explanation for the rapid dispersal of *G. livescens* remain an enigma. Within a radius of approximately 10 meters from the release point, water temperatures did not vary significantly; however, the type of substratum did. Although speculative, the rapid dispersal of this operculate gastropod may be a reflection of its aggressiveness to find suitable food sources. Clampitt (1973) analyzed the stomach contents of five species of snails. He concluded that there was no evidence that snails show a preference for certain foods. It must be noted, however, that *G. livescens* was not one of the five species he studied.

It is evident from this study that differences in the rate and direction of snail movements do occur among various pulmonate and operculate snails. Additional field and laboratory studies are needed to delineate factors that specifically influence these movements.

Acknowledgments

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THE GENUS *BRONDELIA* BOURGUIGNAT, 1862, AND ITS TAXONOMIC POSITION (GASTROPODA: SIPHONARIIDAE)

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ABSTRACT

The genus Brondelia *Bourguignat, 1862, was proposed for two species of* Ancylus *from Algeria. One of them,* A. drouetianus, *had been described by Bourguignat in 1854 from a specimen in the Cuming Collection in the British Museum, supposed to have been collected in North America. This species is here designated as the type-species of* Brondelia. *A study of the original description and figure of* A. drouetianus, *the holotype of which is lost or missing, shows that it is a member of the genus* Williamia *(Siphonariidae). An examination of the original specimens on which Bourguignat based his* Brondelia, *shows that these are* Williamia gussoni *(Costa).* Brondelia *Bourguignat, 1862 is therefore a synonym of* Williamia *Monterosato, 1884. Application is being made to the ICZN to conserve the generic name* Williamia.

In connection with the preparation of an application to the International Commission of Zoological Nomenclature to conserve the generic name *Williamia* (Pulmonata: Siphonariidae), my attention has been called to the name *Brondelia* Bourguignat, 1862, by a recent paper by Bruce A. Marshall (1981), and by John B. Burch, who discussed this generic name in a paper given at the American Malacological Union meetings in Seattle in August 1983.

In order to keep the application to the ICZN as brief and succinct as possible, yet including all pertinent facts, and because Dr. Marshall's paper may not be readily available to readers in this country, I have felt it advisable to present this discussion of the systematic position of the genus *Brondelia*.

At the outset I wish to acknowledge my thanks to Dr. John B. Burch with whom I have had numerous talks about this problem, and who has given me access to his notes, correspondence and borrowed specimens, and is allowing me to publish this paper. Although Marshall in his excellent paper on the genus *Williamia* in the Western Pacific (Marshall, 1981:487-488) has called attention to the fact that *Brondelia* may prove to be an earlier name for *Williamia*, I take this opportunity to make his conclusions more widely known and make some additional observations.

In 1862 Bourguignat proposed the genus *Brondelia* (Bourguignat, 1862:13) for two freshwater limpets from near what is now Annaba (formerly Bône), *B. drouetiana* (Bourguignat, 1854) and *B. gibbosa*, new species. The first species he had described previously (Bourguignat, 1854:92) as *Ancylus drouetianus* from a specimen in the Cuming Collection in the British Museum, the locality being given as North America. In an earlier paper Bourguignat cited the species in a catalogue of Ancylidae as coming from "America" (Bourguignat, 1853:177).

Brondelia has been listed as a section and subgenus of *Ancylus* by Thiele (1931) and Zilch

(1959) respectively. In 1964 Hubendick considered *Brondelia* to be a synonym of *Ancylus* (Hubendick, 1964:21). In a later paper (Hubendick, 1970:27) presented the results of his examination of the original material that formed the basis of Bouguignat's 1862 paper. On the basis of this examination Hubendick considered *Brondelia*, on the principal basis of its distinctly coiled protoconch, to be a distinct genus of unknown taxonomic position, but did comment that the color pattern found in some shells of this lot resembled that found in *Williamia*.

Hubendick calls Bourguignat specimens "type material" but this appellation can apply only to the specimens of *B. gibbosa* Bourguignat. *Ancylus drouetianus* Bourguignat, 1854, as has been pointed out above, is based on a specimen in the British Museum. In his paper Marshall follows Hubendick in calling the material Hubendick examined "type material". He is correct, however, in my view, in assigning these specimens to *Williamia gussoni* (Costa, 1829), although he does so with some reservations. John B. Burch agrees with this determination after personally examining these specimens.

Although the type of *Ancylus drouetianus* Bourguignat, 1854, cannot be found, the rather good description and figure of it (Bourguignat, 1854:92, pl. 25, fig.) confirm the fact that this species is indeed a *Williamia* and probably *W. gussoni* (Costa). The characters given are in my estimation closer to that east Atlantic species than to any American species.

Dr. Burch has visited the locality in Algeria from whence Bourguignat claims his specimens came, and after a careful search was unable to find any specimens of the species.

A valid type species has apparently never been designated for *Brondelia*. Thiele's citation of *B. drouetianus* (Costa) can only be construed as mention of an example (Thiele, 1931:484), and Zilch's designation of *B. drouetianus* as type by monotypy (Zilch, 1959:128) is erroneous as *Brondelia* was based on two species. I therefore hereby designate *Ancylus drouetianus* Bourguignat, 1854 (= *Brondelia drouetianus* Bourguignat 1862) as the type species of *Brondelia* Bourguignat, 1862. Since *A. drouetianus* is a junior synonym of *Williamia gussoni* (Costa, 1829), *Brondelia* Bourguignat, 1862, is a senior synonym of *Williamia* Monterosato, 1884. An application has been submitted to the International Commission on Zoological Nomenclature requesting that the generic name *Williamia* Monterosato be conserved.

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NEW RECORDS AND SYNONYMIES OF BERMUDA OPISTHOBRANCHS (GASTROPODA)[1]

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ABSTRACT

Twenty species of Bermudian opisthobranchs are listed and described, representing significant range extensions, synonymies, or redescriptions of poorly known species with Bermuda type localities. Some biogeographic relationships are discussed. The Bermudian opisthobranch fauna is heavily dominated by a Caribbean component. Species with long pelagic development are often found in low densities, suggesting that this faunal component is recruited allochthonously. Species with encapsulated metamorphosis appear to be better adapted to the island habitat of Bermuda.

Much of the Bermudian opisthobranch fauna was described in the late nineteenth and early twentieth centuries, a period in which most taxonomic descriptions were unfortunately brief, and frequently deficient in the diagnostic characteristics presently used for the separation of species. Approximately 25 original descriptions are from Bermudian coastal waters (Heilprin, 1888; Simroth, 1895; Verrill, 1900, 1901; Smallwood, 1910; Russell, 1935). About 20 of these were described by Verrill. Verrill's descriptions are generally the poorest, usually omitting any reference to internal anatomy, as well as lacking detailed descriptions of external anatomy; his figures were often somewhat stylized and were reproduced at a scale which obscures much detail. These deficiencies are compounded by the apparent loss of most of Verrill's holotypes (Willan, 1978).

Bermuda lies reasonably close to the Antillean Archipelago, and is within the influence of the Gulf Stream, thus should share many species with the Caribbean fauna. Without dependable Bermudian descriptions for comparisons, it is impossible to characterize the Bermuda fauna or the Caribbean fauna accurately; older species cannot be compared with new species, and there may be synonyms among previously described Bermudian and Caribbean species.

The purpose of this study is to redescribe some Bermuda Opisthobranchia in order to clarify the status of these species. Additionally, some information on habitats and diets of Bermuda species is presented, with several new records for these islands.

[1]Contribution No. 984 of the Bermuda Biological Station.

Material Examined

Most of the specimens studied were collected in August 1979 from various sites in eastern Bermuda. Samples were collected by several techniques. Most were collected by vigorously shaking algae, hydroids, etc. underwater, then collecting the dislodged opisthobranchs with a suction collector (Clark, 1971). Others were collected by direct visual inspection of potential substrates. Additional materials were examined in the museum collection of the Bermuda Biological Station (BBS), representing a variety of habitats and seasons; however, the majority of the material examined was collected in summer, and probably represents only a portion of the complete Bermudian opisthobranch fauna. Materials listed were collected by the author unless otherwise noted.

List of Species

Subclass Opisthobranchia

Order **Cephalaspidea**

Runcinidae

1. *Runcina divae* (Marcus & Marcus, 1963)

Order **Anaspidea**

Notarchidae

2. *Stylocheilus longicauda* (Quoy & Gaimard, 1824)

Aplysiidae

3. *Aplysia parvula* Mörch, 1863

Order **Ascoglossa**

Volvatellidae

4. *Volvatella bermudae* Clark, 1982

Oxnoidae

5. *Oxynoe antillarum* Mörch, 1863

Elysiidae

6. *Elysia subornata* Verrill, 1901
7. *Elysia papillosa* Verrill, 1901
8. *Elysia tuca* Marcus & Marcus, 1967
9. *Elysia flava* Verrill, 1901

Boselliidae

10. *Bosellia mimetica* Trinchese, 1890

Caliphyllidae

11. *Cyerce antillensis* Engle, 1927
12. *Cyerce cristallina* (Trinchese, 1881)

Costasiellidae, **new family**

13. *Costasiella ocellifera* (Simroth, 1895)
14. *Costasiella nonatoi* Marcus & Marcus, 1960

Order **Pleurobranchacea** (Notaspidea)

Pleurobranchidae

15. *Berthella agassizii* MacFarland, 1909

Order **Nudibranchia**

Suborder Doridacea

Chromodorididae

16. *Chromodoris bistellata* (Verrill, 1900)

Goniodorididae

17. *Okenia zoobotryon* (Smallwood, 1910)

Suborder Dendronotacea

Tritoniidae

18. *Tritoniopsis frydis* Marcus & Marcus, 1970

Suborder Aeolidacea

Favorinidae

19. *Favorinus auritulus* Marcus & Marcus, 1955

Facelinidae

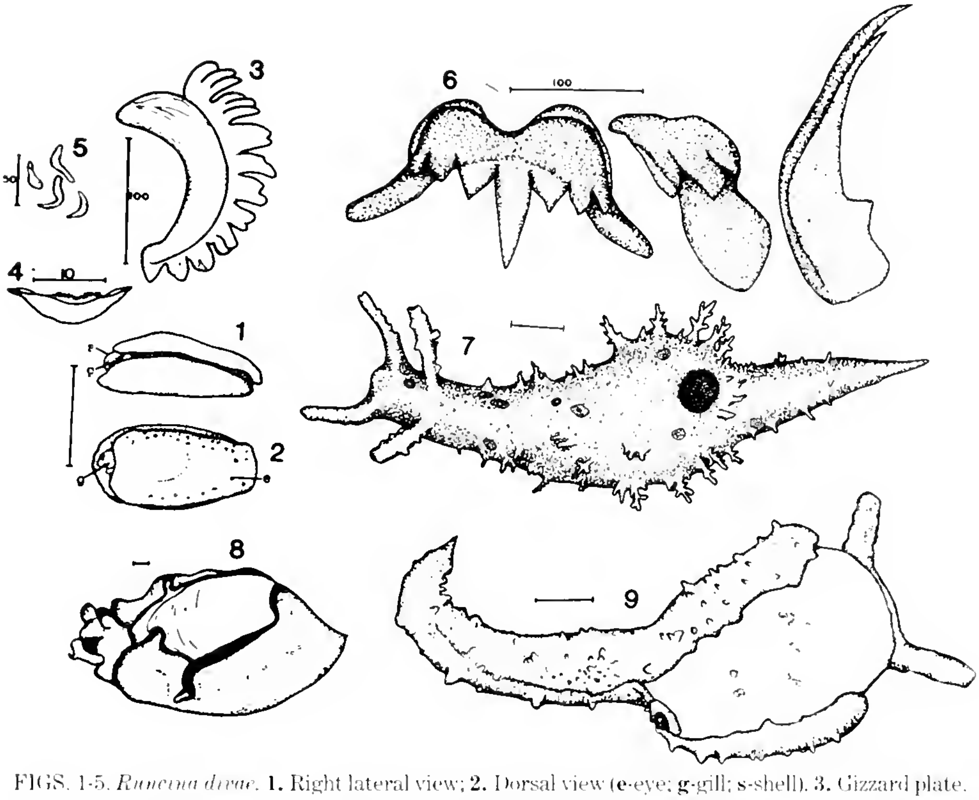
20. *Dondice occidentalis* (Engel, 1925)

Descriptions

1. *Runcina divae* (Marcus & Marcus, 1963)

New combination

(Figs. 1-5)



FIGS. 1-5. *Runcina divae*. **1.** Right lateral view; **2.** Dorsal view (e-eye; g-gill; s-shell). **3.** Gizzard plate. **4.** Rachidian tooth. **5.** Lateral teeth. FIGS. 6-9. *Stylocheilus longicauda*. **6.** Radular teeth (r-rachidian; m-marginal; l-lateral). **7.** Living animal, from photo. **8.** *Aplysia parvula*, preserved animal. **9.** *Oxynoe antillarum*, partially relaxed.

Synonymy:
Ildica dirac Marcus & Marcus, 1963 (Pp. 7–9, Figs. 1–7; Piscadera Bay, Curaçao).
Lapinura divae (Marcus & Marcus, 1963) (Marcus & Marcus, 1970, pp. 19–22, Figs. 20–26).

Localities: East side of Trunk Island, depth 1 m, on *Codium* (coll. by W. Sterrer); North side of causeway, Castle Harbor, on *Caulerpa racemosa*.

Description: Length, 1-2 mm; body smooth, elongate elliptical, with lateral groove separating body into ventral foot and undivided dorsal mantle. Color reddish brown. Plicate gill of several indistinct lobes located near midline of hind end, partially covered by overlapping end of posterior mantle. Shell, when present, small, hyaline, located to left of gill and also partially obscured by mantle (Figs. 1, 2). Eyes and digestive gland faintly visible through mantle of living animal (Fig. 2). Gizzard with about 10 ridges (Fig. 3); radula 21-23 × 1:1:1; laterals variably hooked, rachidian tooth with about 18 very delicate denticles on weakly notched central cusp (Figs. 4, 5).

Comments: The external shell was absent in most specimens (about 75%) from Trunk Island, and present in most from Castle Harbour; its absence was confirmed by dissection and by sodium hydroxide treatment of several animals during radula removal. The median notch of the rachidian tooth was somewhat less distinct than described by Marcus and Marcus (1963).

Presence of an exposed larval shell in the adult animal was used by Marcus & Marcus (1970) to define the genus *Lapinura*. However, the variability of this character in Bermudan populations of this species indicates that this character cannot be used to establish a separate genus. This characteristic may be ontogenetically variable, with loss of the shell occurring sometime between juvenile and adult phases in some animals. If one disregards presence of the larval shell, then major characteristics of this species (radula 1:1:1, 4 gizzard plates) clearly place it in *Runcina* (see Kress, 1977).

Verrill's *Runcina inconspicua* (1901) differs in the presence of orange or violet marginal bands on notum and foot, and the gill was described as composed of fine filaments, so *inconspicua* must be distinct from *divae*.

2. *Stylocheilus longicauda* (Quoy & Gaimard, 1824)
(Figs. 6, 7)

Synonymy:
Aplysia longicauda, Quoy & Gaimard, 1824 (New Guinea).

Locality: eastern Bermuda; collection data for the single animal in the Bermuda Biological Station are missing. Tucker Abbott informs me (*in litt.*) that he has collected this species intertidally on the southshore of Tucker's Town. However, this species typically occurs in reef rubble, associated with fine filamentous rhodophytes.

Description: a color photograph of the specimen shows typical coloration for this species, a mottled greyish body with orange-ringed iridescent blue eyespots scattered over the dorsal mantle.

3. *Aplysia parvula* Mörch, 1863
(Fig. 8)

Locality not given; collected 10 June 1979, W. Sterrer.

Description: This species is easily recognized as a small *Aplysia* with a narrow foot, and black parapodial margin, rhinophore tips, and foot borders; body light brown with small lighter mottlings. The preserved specimen is 17 mm long, with the relatively large shell plate (½ of body length) lightly calcified and chalky.

4. *Volvatella bermudae* Clark, 1982

Locality: On *Caulerpa racemosa* on vertical rock faces, 1-3 m.

Description: Strong, channeled shell with apical "spout"; mantle green, foot white. This species was believed to be endemic to Bermuda when described (Clark, 1982a), but also occurs on mangrove roots in Belize (*own obs.*) on Caulerpa racemosa. Mangrove seems to be the prime habitat in Belize, with *Rhizophora* roots providing a habitat similar to vertical rock walls in Bermuda. The Bermuda animals are probably a population on the northern fringe of its range.

5. *Oxynoe antillarum* Mörch, 1863
(Fig. 9)

Localities: common at Tobacco Bay, Whalebone Bay, and occasional specimens at Castle Harbour Causeway; on *Caulerpa racemosa* to depths of 3 m, in areas of good cir-

culation, usually occurring with *Volvatella bermudae* (Clark, 1982a).

Description: Body green, to 3 cm, with glossy, inflated shell covering middle body; shell partially covered by adherent parapodia; greyish spots on elongate, greenish tail, with scattered papillae on parapodia, tail and body. This species is easily confused with *O. azuropunctata* K. R. Jensen, but Bermuda specimens have planktotrophic larvae, so are *O. antillarum*.

6. *Elysia subornata* Verrill, 1901
(Figs. 10-14)

Synonymy:

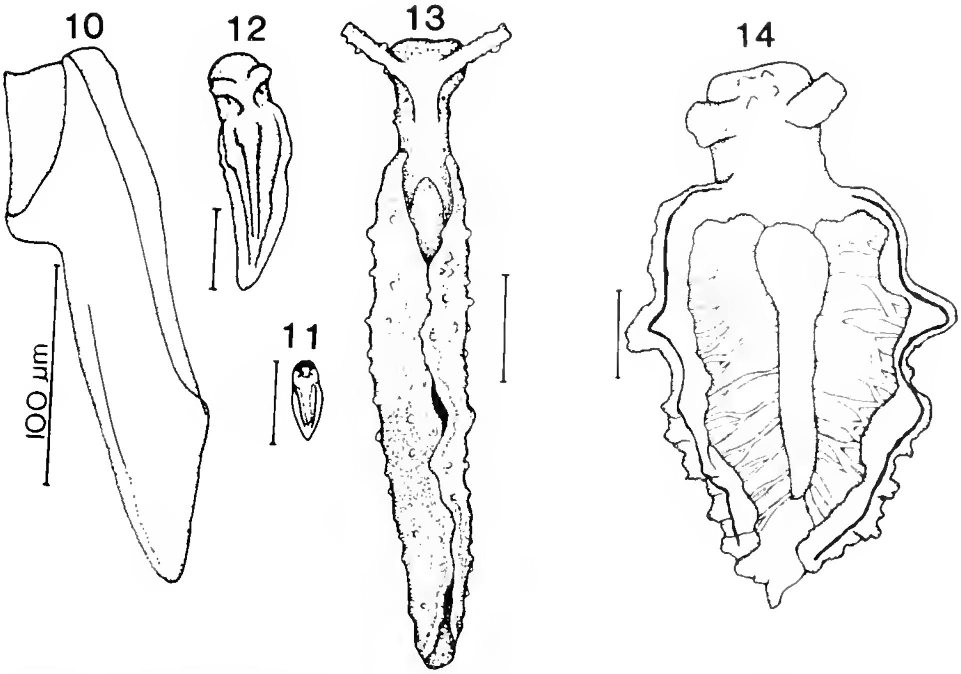
Elysia subornata Verrill, 1901 (Pp. 29-30, Pl. 4, Fig. 1; Castle Harbour, Bermuda).

Elysia cauze Marcus & Marcus, 1957 (Pp. 405-410, Figs. 35-44; Sao Sebastiao Island, Brazil).

Localities: very abundant at SW end of causeway, Castle Harbour; common at Tobacco Bay, Whalebone Bay, Bailey's Bay; on *Caulerpa racemosa*, to 2 m.

Description: Specimens within single populations were often highly variable in coloration, ranging from yellow green to dusky olive to reddish, usually with brownish to black parapodial margins (pale or absent in some specimens). Parapodial margin thickened, whitish. Parapodia usually minutely papillose, sometimes smooth; heavily ruffled in larger specimens. Parapodia often bear white spots, with or without black rings. Rhinophores usually banded with irregular transverse grey or white band, with distal transverse brownish band. Small juveniles show the distinctive black "facial mask" described for Florida specimens (Clark *et al.*, 1979). Renopericardium long (ca. ½ total body length), extending most of distance to tip to tail, with about 10 vessels extending perpendicularly from each side to the base of the thickened parapodial margin, branching more or less dichotomously, sometimes anastomosing (Fig. 14). Radular tooth minutely denticulate (Fig. 9). Body length to 50 mm; one of the largest Atlantic ascoglossans.

Comments: the range of variation of the specimens collected here includes all characteristics of Verrill's (1901) brief description and figure (except that the marginal line of the parapodia is rarely orange-brown) and does not significantly differ from characteristics of *E. cauze*. The marginal black band is a character found in several described and undescribed



FIGS. 10-14. *Elysia subornata*. **10.** Tooth. **11, 12.** Juveniles. **13.** Adult, at rest. **14.** Adult, parapodia extended to show pericardial complex.

Caribbean and Florida *Elysia*, but as Marcus (1980) notes, the long renopericardium and the dorsal vessel pattern "are an exceptional feature of the species." Although Bermuda animals are more variable in color than Florida populations, there seems no valid reason to regard them as a distinct species.

The unusual reddish color of specimens from Castle Harbour causeway was associated with relatively eutrophic water and a consequent growth of reddish epiphytic Cyanophyta on the *Caulerpa*.

7. *Elysia papillosa* Verrill, 1901

(Figs. 15-20)

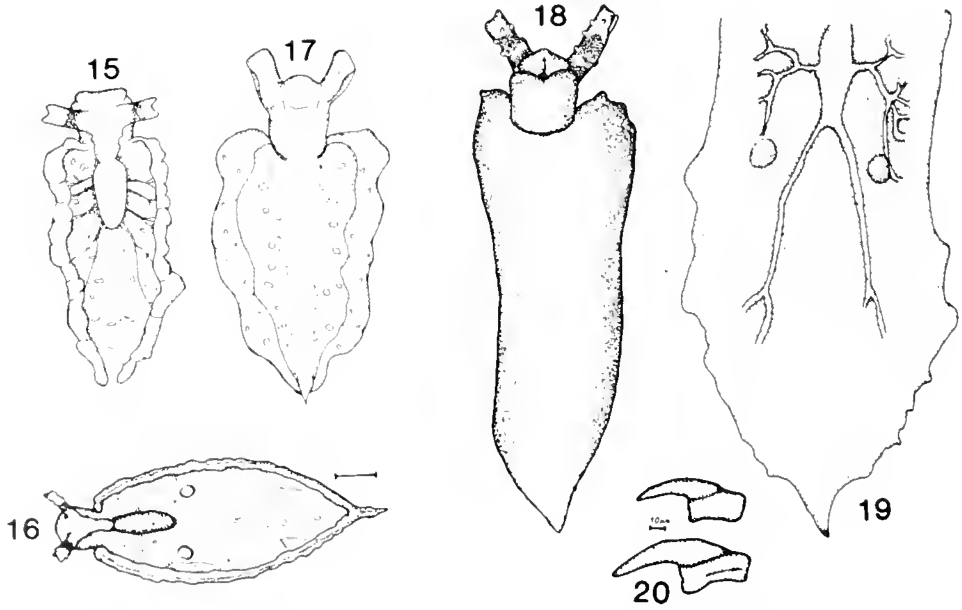
Synonymy:

Elysia papillosa Verrill, 1901 (p. 31, Pl. 4, Fig. 3; Hungry Bay, Bermuda).

Localities: widely distributed: Castle Harbour; Bailey's Bay; Ferry Reach; Hungry Bay; Tucker's Town Bay; Harrington Sound; feeding upon *Halimeda* spp., *Penicillus*, and *Udotea flabellum*, to 4 m depth.

Description: Body pale green with thick white parapodial margins, white head and parapodia, brown transverse bands on parapodia, numerous white papillae on both surfaces of parapodia, head, and rhinophores; pericardium brownish; iridescent white blotches are scattered on the upper surface of the parapodia, increasing in size toward the tail. A line of scattered brown granules occurs on the white parapodial margin, forming a distinct black line in larger animals (> 1 cm). Foot lighter green than parapodia. A prominent sperm-filled vesicle lies at about the middle of each side of the upper parapodium surface. Pericardial hump short, with one to three pairs (dependent on size) of vessels radiating laterally, one pair posterolaterally (Fig. 19). In some specimens, especially larger ones, the posterolateral vessels originate as a single posteriorly directed vessel which divides part way between the pericardium and the tail (Fig. 19). Specimens from southern Castle Harbour, from *Udotea*, were olive green and lacked papillae but in other respects were typical *papillosa*.

Comments: Non-Bermudan records of *E. papillosa* are tied to a description of Florida animals (Marcus & Marcus, 1967), which noted that Verrill's description lacked critical characteristics. The present observation validates the Marcus' conclusion that non-Bermudan records represent the same species. *E. patina* Marcus, 1980 is similar to *E. papillosa* in the presence of "gametolytic vesicles" and dentition; a more thorough description of *patina*



FIGS. 15-20. *Elysia papillosa*. **15**, **16**. Dorsal views of two animals, illustrating variability. **17**, **18**. Ventral views. **19**. Pericardial complex, **20**. Teeth.

from living animals would aid separation of the two species. Dissection of "gametolytic vesicles" in several living animals of *E. papillosa* and Florida specimens of *E. patina* showed that they were filled with highly motile sperm; these structures appear to function as storage vesicles for viable sperm, and the term "gametolytic" should be replaced by "gametic" until function is defined.

8. *Elysia tuca* Marcus & Marcus, 1967
(Fig. 21)

Synonymy:
Elysia crispa (Morch, 1863) Verrill, 1901.

Localities: common in Ferry Reach; Harrington Sound; on *Udotea*, *Halimeda*, and *Penicillus;* to 3 m, especially in areas of quiet water.

Description: Body dark green, with irregular iridescent white patches on parapodial margin and on head between rhinophores; parapodia smooth, held tightly rolled against midline of body, with distinct mid-length notch forming a ventilatory "chimney". Length to 15 mm.

Comments: This species is easily separable from all other Caribbean species by the parapodial notch, coloration, diet, and posture. Verrill's description noted the distinctive white patch between the rhinophores, but erroneously identified the species as *Tridachia crispata*. This has led to some confusion that *Tridachia crispata* occurs in Bermuda; it apparently does not. This also explains why *E. tuca*, which is ubiquitous throughout the Caribbean, has not been previously reported from Bermuda.

9. *Elysia flava* Verrill, 1901
(Figs. 22-24)

Synonymy:
Elysia flava Verrill, 1901 (P. 30, Pl. 4, Fig. 1)

Locality: A single specimen, collected by W. Sterrer, Hungry Bay, June 1979, depth 0.1 m.

Description: Body yellow, with irregular dark green longitudinal band extending along

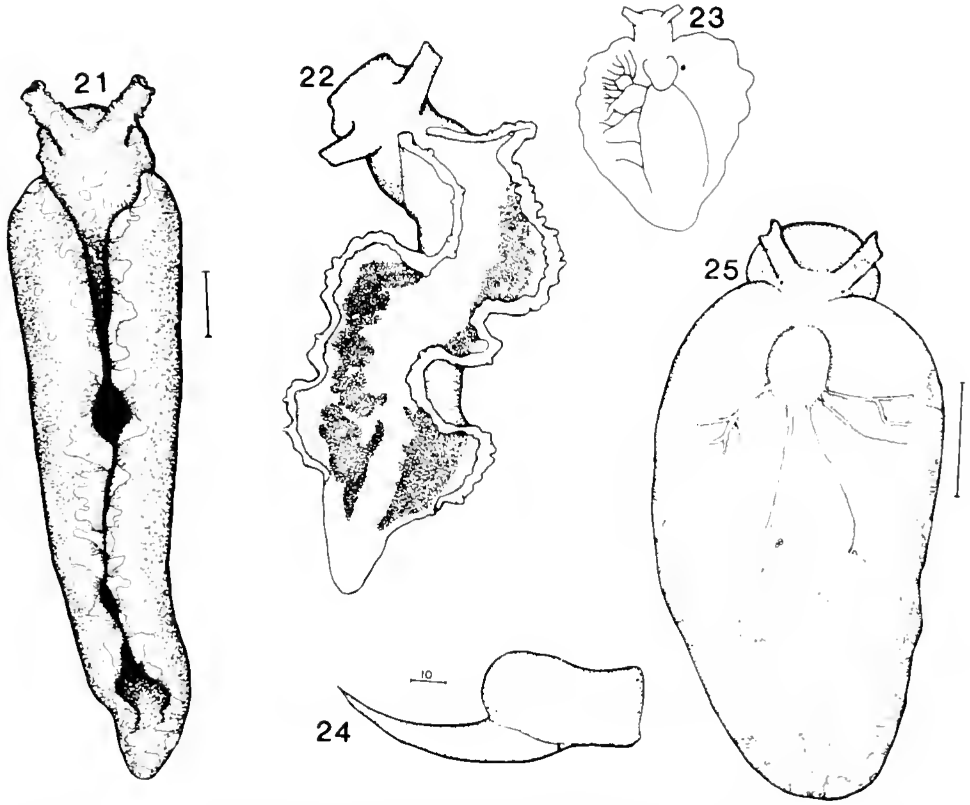


FIG. 21. *Elysia tuca*. FIGS. 22-24. *Elysia flava*. **22.** Dorsal view, from photo of living animal. **23.** Venation of pericardial complex. **24.** Tooth. FIG. 25. *Bosellia mimetica*.

parapodium on each side (color represents digestive diverticula); parapodial margin white. Pericardium short, with single posterolateral vessel on each side, which branches near pericardium (Fig. 0), forming a long posterad vessel with a dense cluster of anastomosing vessels. Teeth small (56-80 μm) and relatively uniform in length, with narrow cutting tip, edenticulate; 31 radular teeth in the single specimen.

Comments: Thompson's (1977) Jamaican record of *E. flava* is the first non-Bermudan record and correctly redescribes this species. The tooth of *E. flava* is similar to that of *E. papillosa*, suggesting that this species may feed on *Udotea*, but its diet is so far unknown. At the time of my visit to Hungry Bay, there were no visible Siphonales suitable as food for this species. It is possible that the yellow color of the parapodia is due to starvation. This species is quite similar to *E. papillosa* and *E. patina* Marcus, and further studies are needed to adequately define differences between these species.

10. *Bosellia mimetica* Trinchese, 1890
(Fig. 25)

Locality: One specimen, SW end of Ferry Reach; on *Halimeda*, d. 2 m.

Description: Body flat, plastic in outline, but elliptical when at rest, closely conforming with and adhering to scales of *Halimeda;* color deep green with white irregular patches, concentrated at margins. Pericardium ovoid, with about 5 dendritic posterolateral vessels. Tooth robust, strongly hooked, with strong denticles. L. 15 mm.

Comments: As Marcus (1982) notes, the genus *Bosellia* should be placed in its own family by virtue of its chromosome number. Also, the adherent flattened "parapodia" of *Bosellia* are distinctly different in morphology and function from those of *Elysia*, since they are not rolled but are used to adhere to the substrate. Actually, the "parapodia" of boselliids are not true parapodia, but represent a very broad foot; in elysiids, the parapodia are lateral extensions of the dorsolateral body wall and extend well beyond the foot, which is narrow and well-defined. In *Bosellia* the margin of the foot is directly joined to the dorsal body surface. Also, the radular teeth of *Bosellia* are quite different from those of elysiids which eat *Halimeda*. *B. mimetica* has a broad distribution, including Europe and the Mediterranean as well as throughout the Caribbean. In Florida, this species is most abundant in areas with heavy wave action (Jensen & Clark, 1983), and the broad foot may be adaptive to this high-energy habitat.

11. *Cyerce antillensis* Engel, 1927
(Figs. 26-29)

Locality: Ferry reach, uncommon on *Penicillus dumetosus*, to 1 m.

Description: Body whitish to yellowish, occasionally deep green, with flat, colorless, transparent cerata. Body flattened, with broad foot. Cerata easily detached, adhesive, lacking digestive diverticula. Rhinophores deeply bifid, rolled.

12. *Cyerce cristallina* (Trinchese, 1881)
(Figs. 30-31)

Synonymy:
Lobancoia cristallina Trinchese, 1881 (P. 116, Figs. 1-12; Naples, Italy).

Locality: Hungry Bay, a single specimen coll. by W. Sterrer, 1 m. depth.

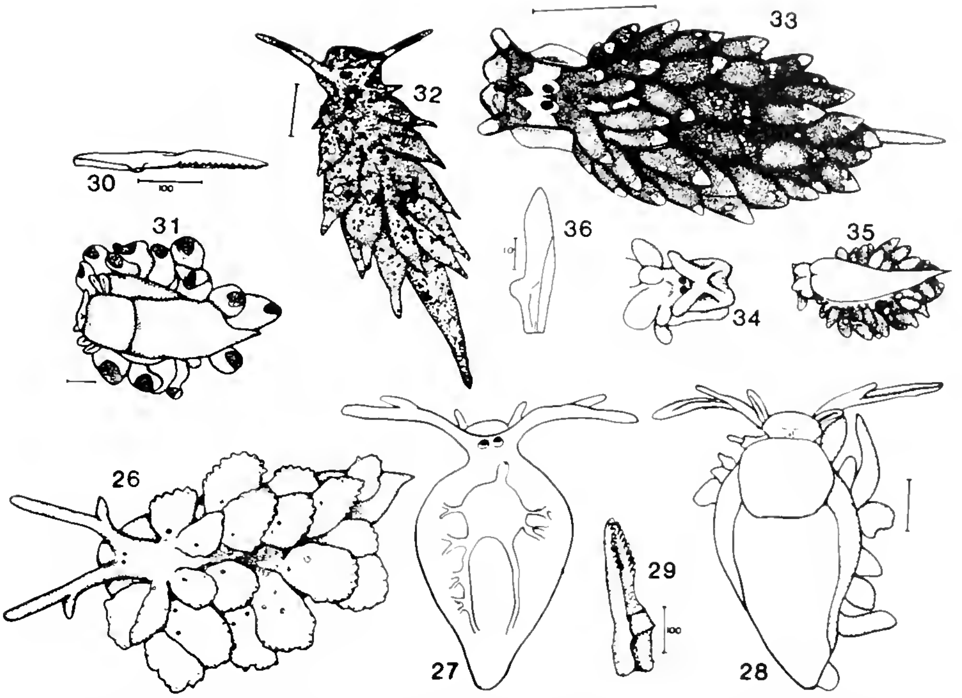
Description: Body translucent, whitish, with conspicuous white patches on head, rhinophores, and transparent cerata, and bright red patches overlying the white. Radular teeth very long (300 μm) and constant in length; about 15 denticles per side. Length 7.5 mm.

Comments: The bright coloration of this species easily separates it from *C. antillensis*. *C. cristallina* is far less common than *C. antillensis*, and its diet and development are unknown.

Costasiellidae, New Family

As Clark (1982b) noted, the genus *Costasiella* is transitional in characteristics between Stiligeridae and Caliphyllidae, but differs in most characteristics from the other transitional hermaeid genera *Hermaea* and *Aplysiopsis*.

Diagnosis: ceratiform Ascoglossa with large admedian eyes, fusiform non-flattened cerata, unifid auriculate or digitiform rhinophores broadly joined to the snout via the anterior edge; digestive diverticula usually knobby, in grapelike clusters within cerata; genital apertures polyaulic (rather than diaulic as in *Hermaea* or *Aplysiopsis*). Foot rather narrowly



FIGS. 26-29. *Cyerce antillensis*. **26.** Dorsal view, from photo. **27.** Pericardial complex. **28.** Ventral view (p-penis). **29.** Tooth. FIGS. 30-31. *Cyerce cristallina*. **30.** tooth. **31.** Ventral view. FIG. 32. *Costasiella ocellifera*. Dorsal view, from photograph. FIGS. 33-36. *Costasiella nonatoi*. **33.** Dorsal view. **34.** Head. **35.** Ventral view. **36.** Teeth.

triangular; radular teeth non-denticulate; esophageal diverticulum absent; visceral loop with three ganglia. Diet, *Avrainvillea* for species with known diet; distribution tropical.

13. *Costasiella ocellifera* Simroth, 1895 **new combination** (Fig. 32)

Synonyms:

Doto ocellifera Simroth, 1895 (Pp. 168-170, Pl. 20, Figs. 6-10; St. George's Harbour, Bermuda)

Stiliger lilianae Marcus & Marcus, 1969 (Pp. 7-12, Figs. 22-28; Sao Paulo, Brazil)

Costasiella lilianae (Marcus & Marcus), Baba, 1970

Costasiella lilianae (Marcus & Marcus), Thompson, 1977

Localities: Ferry Reach; Bailey's Bay; common on *Avrainvillea* to 2 m.

Description: Color whitish, but appearing deep green, due to dense chloroplasts in digestive diverticula; cerata and body covered with scattered large black round chromatophores; faint orange rings surround cerata near distal tip; bluish-green iridescent spots and small whitish glands scattered on cerata; a green iridescent spot, surrounded by a yellow ring, is located between the large eyes and the pericardium. Rhinophores long, cylindrical, tapering, with auriculate base; cerata pyriform (fusiform in relaxed animals), arranged in five to six diagonal rows on each side, four cerata per row; cerata separated from the foot by a shallow furrow. Posterior foot divided by transverse groove and containing digestive diverticula, appearing much like a ceras. Radular teeth uniform in size, about nine teeth in the ascending arc and 10-12 in the descending; ascus absent.

Comments: Ferry Reach, from which the present material was collected, is an extension of Simroth's type locality, St. George's Harbor. His figures, apparently of preserved material, clearly show the grape-like digestive diverticula, large admedian eyes, and conspicuous melanophores of the species later described as *Stiliger lilianae*. Simroth's Fig. 8 also shows the distinctive eye structure (heavily pimented cup enclosing a hyaline lens) as shown by Marcus & Marcus (1969, Fig. 27) for *St. lilianae*. Simroth's figure of the radula (his Fig. 10) appears slightly different than teeth of *Costasiella*, as if he failed to include the laminar edge of the tooth. This

may be the result of uncritical observation, but the teeth as figured are definitely ascoglossan, and show the uniform size of *C. lilianae*. Simroth also failed to note any transverse demarcation of the posterior foot, but the remaining similarities are so striking that *C. lilianae* is undoubtedly a junior synonym.

Colors of the "eyespot" anterior to the pericardium vary: Florida specimens have a blue spot with orange ring (personal observation) and Jamaican specimens a yellow ring and blue spot (Thompson, 1977).

14. *Costasiella nonatoi* Marcus, 1960
(Figs. 33-36)

Synonymy:
Costasiella nonatoi Marcus & Marcus, 1960 (Pp. 149-152, Figs. 26-33; Ubatuba, Middle Brazil).
Placida nonatoi (Marcus & Marcus, 1960) Marcus & Marcus, 1963.

Locality: Uncommon on *Avrainvillea nigricans* in Ferry Reach, occurring together with *Costasiella ocellifera* to 2 m.

Description: Body whitish, with much melanic pigmentation. Cerata black, except tips, with greenish knobby diverticula visible in some specimens; scattered white areas toward tips of cerata. A distinctive whitish mask surrounds the large black eyes. Rhinophores short, with white tips, fused to each other anteriorly and to the snout at their anterior base; snout of head forming two broadly rounded lobes. Cerata clavate, arranged in 3-4 densely packed rows on each side. Foot not transversely divided; tail long and narrow. Length, to 5 mm.

Comments: Individuals burrow into the felty thallus of *Avrainvillea* to feed and deposit egg masses, and are difficult to collect because this prevents easily dislodging animals. The small size of the adults and melanic coloration also makes them difficult to observe while in the alga. This habit differs from that of *C. ocellifera*, which crawls directly on the surface of the alga, and may represent a fine partitioning of an otherwise highly similar niche. The melanic coloration and location within the alga makes retention of symbiotic chloroplasts in this species unlikely, though *C. ocellifera* is one of the best examples of this phenomenon (Clark *et al.*, 1981).

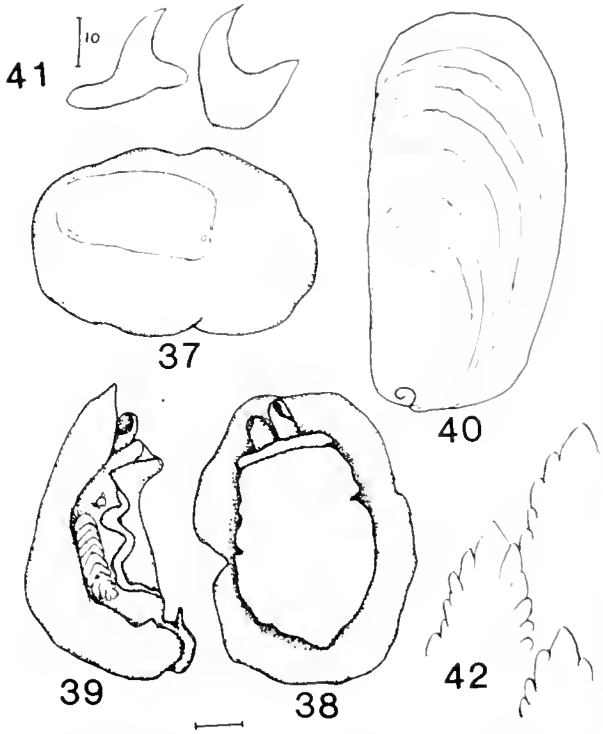
15. *Berthella agassizii* (MacFarland, 1909)
(Figs. 37-42)

Synonymy:
Pleurobranchus agassizii MacFarland, 1909 (Pp. 59-64, Pl. 11-12, Figs. 43-57; Riacho Doce, Alagoas, Brazil).
Bouvieria agassizi (MacFarland, 1909) Odhner, 1926

Locality: Hungry Bay (coll. by S. Gardiner); Gravelly Bay; under rocks, depth 1 m.

Description: Color white, pink, or orange; shell internal, flat, nearly rectangular, slightly longer than half of mantle length, transparent in living animal, with strong growth lines and flat spire. Notum smooth to "orange peel" texture, overlapping foot; gill rachis non-tuberculate, with 12-14 plumules on each side of axis; anus above third or fourth gill leaflet. Radular teeth thornlike (Fig. 41); Jaw scales with 7-11 strong denticles.

Comments: This species closely matches the description of *Pleurobranchopsis aurantiaca* Verrill, 1900, except that Verrill's description explicitly noted the absence of a shell. As noted here, the shell is highly transparent and easily overlooked in live animals, and this might explain Verrill's establishment of the shell-less



FIGS. 37-42. *Berthella agassizii*. **37.** Dorsal view, preserved animal. **38.** Ventral view. **39.** Right lateral view. **40.** Shell. **41.** Teeth. **42.** Jaw scales.

genus *Pleurobranchopsis*. Willan (1978) reviews the history of *Pleurobranchopsis* and *Gymnotoplax*, which appear to be based on inaccurate description and damaged specimens. However, Verrill's description of *P. aurantiaca* lacks sufficient diagnostic characteristics to allow synonymy with *B. agassizi* in the absence of the holotype; thus, *P. aurantiaca* and *P. nivea* must remain *nomina dubia*. *Berthella tupala* Marcus, 1957, differs from *B. agassizi* by melanic pigmentation of the shell and differences in jaw scales.

16. *Chromodoris bistellata* (Verrill, 1900)
(Fig. 43)

Synonymy:
Doris bistellata Verrill, 1900 (P. 548, Pl. 66, Fig. 2; Castle Harbour).

Locality: Coney Island, summer 1976.

Description: Gills 5, simply pinnate (Verrill notes 7) with alternating leaflets; mantle skirt high, as in *Hypselodoris:* Radular teeth hamate, non-denticulate, tapering in size from adlaterals (48 μm) to admedian (36 μm), 30 × 36.0.36. Notum deep brown, with two white stellate spots and scattered flecks of white. The dentition of this species clearly places it in *Chromodoris*. The preserved animal is 5 mm length; Verrill's original specimens were 15-20 mm.

17. *Okenia zoobotryon* (Smallwood, 1910)
new combination
(Figs. 44-47)

Synonymy:
Polycerella zoobotryon Smallwood, 1910 (PP. 143-145, Fig. 10; Agar's Island (?), Bermuda)
Bermudella zoobotryon (Smallwood, 1910) (Odhner, 1941)
Okenia evelinae Marcus, 1957
Cargoa evelinae (Marcus, 1957) (Vogel & Schultz, 1970)

Locality: Hall's Island, Harrington Sound, on the bryozoan *Zoobotryon pellucida*, under rock ledges 1-5 m.

Description: Radula 1.1.0.1.1 × 18; lateral 50 m wide, with about 11-12 denticles; marginal 20 μm wide, with distinct notch on distal edge. Body white with brown spots scattered on spiculate notum; foot narrow, with slight foot

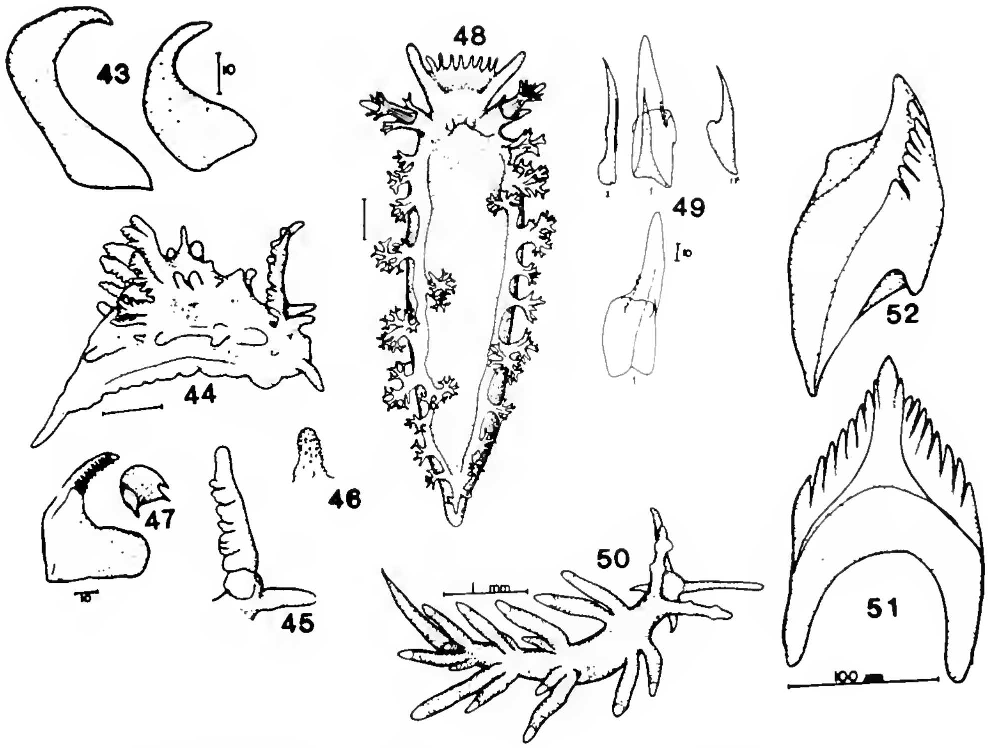


FIG. 43. *Chromodoris bistellata*, teeth. FIGS. 44-47. *Okenia zoobotryon*. 44. Lateral view. 45. Rhinophore. 46. Papilla. 46. Teeth. FIG. 48. *Tritonia frydis*. 48. Dorsal view. 49. Teeth. FIG. 50. *Favorinus auritulus*, from photo of live animal. FIGS. 51-52. *Doridice occidentalis*, teeth. 51. Vertical view. 52. Lateral view.

corners. Pallial ridge bears several short papillae; pericardial hump guarded by two papillae on each side; up to 7 simply pinnate gills. Rhinophores white, with 5-7 cup-shaped lamellae (irregular in relaxed animal), blunt anterior-pointing basal spur. Notal papillae studded with small tubercles, possibly toxic. L. to 6 mm.

Comments: This small dorid is highly conspicuous on the transparent masses of *Zoobotryon*, collected from the type locality of *Polycerella zoobotryon* in Harrington Sound (Smallwood, 1910). The present material agrees in all respects with Smallwood's type description, but he later described the radula in a secondary description (Smallwood, 1912) with three lateral teeth. In other respects, the similarity is so strong that this secondary description must be regarded as erroneous or possibly variable. In my material, the laterals stained very poorly with acid fuchsin and most scattered during preparation, so this discrepancy may be understandable, and may explain why this species has not been properly placed before. *Okenia evelinae* differs only in color of the rhinophores (purple) and size and number of rows of radular teeth, which may be due to variations in diet and size. Specimens from Sebastian Inlet, FL also feed on *Z. pellucidum* and have the same coloring as Bermuda specimens. Vogel and Schulz (1970) differentiated *O. cupella* from *O. evelinae* solely on the basis of the number of cupped rhinophoral lamellae. As their specimens were quite small (2 mm), this may be an unreliable character and this species is probably synonymous.

18. *Tritoniopsis frydis* Marcus & Marcus, 1970
(Figs. 48-49)

Locality: West of Nonsuch Island, Castle Harbour, on base of *Gorgonia*, 3 m. This area contains scattered corals and has a heavy algal growth. Three specimens, to 0 mm.

Description: Body white to orange; dorsal papillae 8-12 per side, dendritic, brownish, resembling gorgonian polyps. Rhinophoral sheaths and clubs similarly dendritic. Oral veil with 2 large and about 8 short digitiform tentacles. Anus midlateral. L to 20 mm.

19. *Favorinus auritulus* Marcus & Marcus, 1955
(Fig. 50)

Locality: Ferry Reach, on *Penicillus* and *Caulerpa*, where it feeds on the eggs of other opisthobranchs; depth, to 2 m.

Description: The knobbed rhinophores, short, recurved foot corners, and oral tentacles of the same length as the rhinophores characterize this small (5-12 mm) aeolid. Cerata in 3-4 small groups. Color dull white or beige. Radula uniseriate, unicuspid, non-denticulate. This species is easily cultured and can become a "pest" contaminant of cultures of other slugs.

20. *Dondice occidentalis* (Engel, 1925)
(Figs. 51-52)

Synonymy:
Caloria occidentalis Engel, 1925 (Pp. 41-44, Figs. 7-15; Montego Bay, Jamaica.)

Locality: Pt. Shares, Great Sound, July 1979.

Description: This species is easily recognized by the black jaw epithelium, visible through the head in living or preserved animals. Radula uniseriate; tooth with 8 denticles, the first pair smaller and closely adherent to the central cusp; jaw denticles were not visible in the single preserved specimen. Oral tentacles very long, foot corners short. Cerata in six groups. Color whitish; iridescent white patches on head, nape, and sides visible in preserved animal. Length of preserved animal 9.5 mm.

Comments: This species agrees in some physical characteristics with *Facelina* (?) *goslingii* Verrill, 1901, but that species has radular teeth with 10-12 denticles of decreasing size, black jaws are not mentioned, and there are differences in coloration. The differences in dentition alone are enough to separate the two species.

Discussion

Prior to this study, Bermudian opisthobranchs appeared to have a large proportion of endemic species. However, when synonymies are considered, this proportion falls, and the predominantly Caribbean characteristics of this group are evident. The largest endemic component is seen among the dorid Nudibranchia, in which several of Verrill's species (*Doris olivacea*, *Lamellidoris lactea*, *Lamellidoris quadrimaculata*, *Chromodoris roseopicta*, *La-*

mellidoris aureopuncta, Lamellidoris miniata) are dissimilar from known Caribbean species. The nudibranchs are fairly well-known from other Caribbean studies (see Marcus, 1980, for a summary), and it appears that most of these species are true Bermudian endemics.

Resolution of the status of these species must unfortunately depend on re-collection, as generic placement by current standards is quite dubious. Most of the remaining endemic species of questionable status were collected in spring, hence their absence in the present study is not evidence of non-occurrence. However, increasing human activity in Bermuda, with consequent alteration of habitat, creates a distinct possibility that these species may have disappeared, or will disappear, from Bermuda waters. In such case, the identity of these species may never be resolved, and efforts should be made to collect and redescribe these species at the earliest opportunity.

The densest populations of Bermudain opisthobranchs seem to be those species with brevipelagic development (e.g. *Elysia subornata, Elysia tuca, Elysia papillosa, Costasiella ocellifera, Bulla striata, Haminoea antillarum*). Species with extended pelagic development are, in contrast, sparse in population though well-represented in number of species (e.g. *Elysia ornata, Bosellia mimetica, Oxynoe antillarum, Tritonia frydis*), particularly when compared with mainland Florida populations with similar food resources. This suggests that species with pelagic development recruit primarily via allochthonously produced larvae originiating on Bahaman or other Caribbean shores, and that such Bermudian species are effectively sterile populations. If this is true, one might predict that 1) brevipelagic development will dominate among Bermudian endemics, and 2) Bermudian species with brevipelagic development will be genetically more distant from Caribbean conspecifics than species with longipelagic development.

Some interesting taxonomic questions remain. Smallwood's *Facelina agari*, with tuberculate rhinophores, probably belongs in *Berghia*, but the description, from a single animal, gives very few useful characteristics. The primitive sketch of the animal (Smallwood, 1910) is of little use in identification. Several others of Verrill's species (*Coryphella pallida, Runcina inconspicua, Facelina goslingii*) require further evaluation, as they cannot reliably be placed even to genus without reexamination.

Additional, previously recorded species of Bermuda Opisthobranchia are summarized and illustrated in Jensen and Clark (in press).

Acknowledgments

This research was supported by a Samuel Riker Fellowship of the Bermuda Biological Station. Dr. Wolfgang Sterrer was especially helpful as a collection partner and did much to acquaint me with collection sites in Bermuda.

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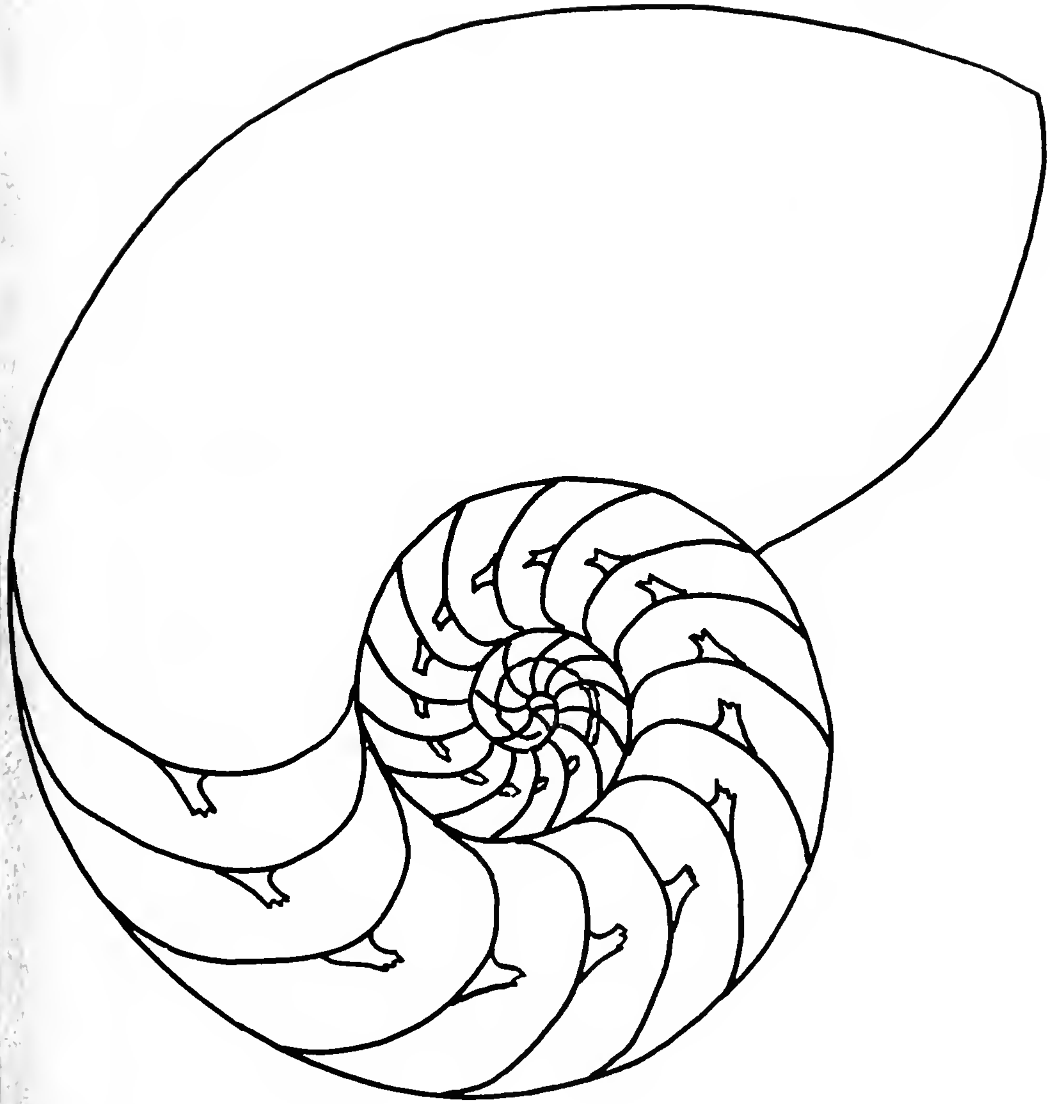

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CONTENTS

MEETING

The Western Society of Malacologists will hold its 17th Annual Meeting on the campus of the University of California, Santa Cruz, California, on August 16–19, 1984. *All* persons interested in mollusks, whether they be amateur shell collectors or professionally trained malacologists, are invited to attend. For further information, please contact Dr. George L. Kennedy, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025. (415-323-8111, ext. 2634).

NATICA GUESTI, A NEW NATICID GASTROPOD FROM THE WESTERN ATLANTIC

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For more than a decade the deep-water trapping operations of the Lightbourn-Guest North Star Expeditions, conducted off the south shore of Bermuda, have brought up numerous hermit-crab-borne molluscan shells. Many of these specimens represented considerable range extensions (Finlay, 1978; Finlay and Vink, 1982; Snyder 1984) and several new species (Harasewych and Jensen, 1979; Snyder, 1984; Okutani and Goto, 1983). Included in this material were numerous examples of a new species of naticid that is described herein.

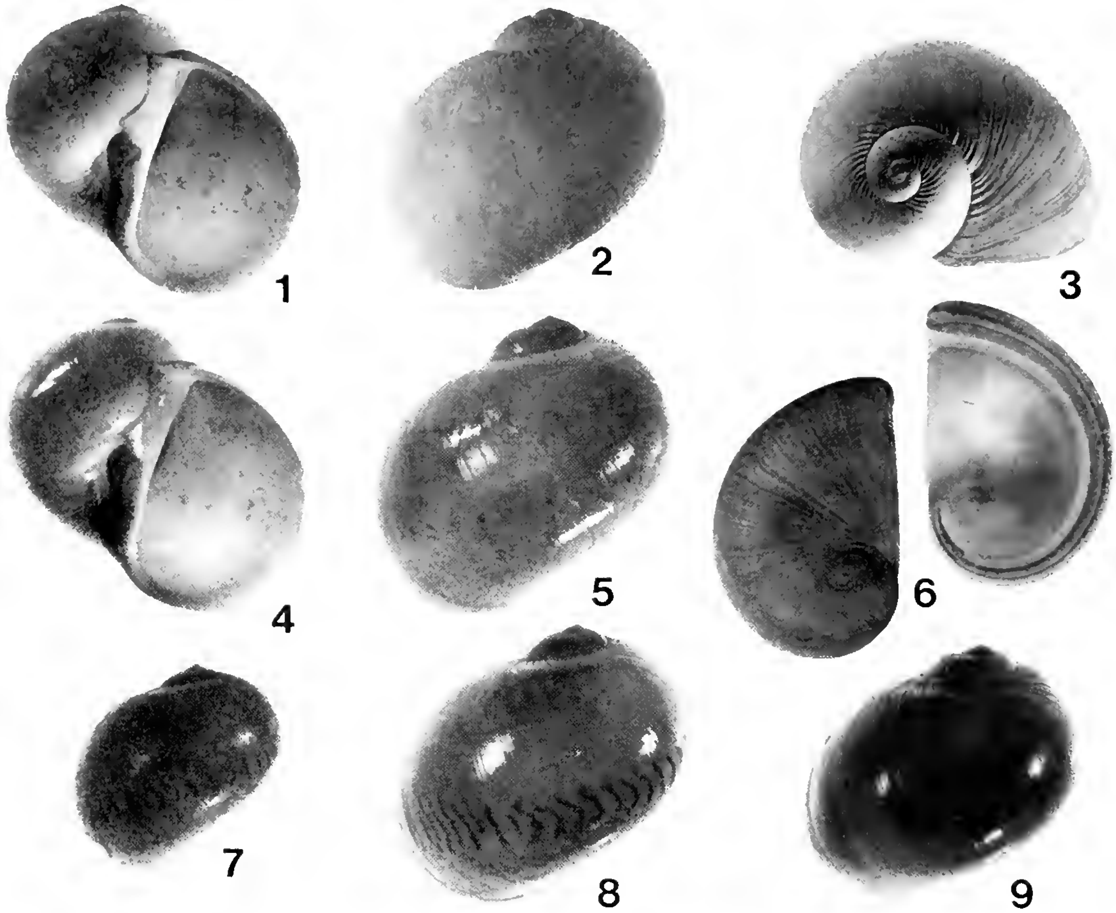
Examination of the molluscan collections at the Museum of Comparative Zoology, Harvard University, and at the National Museum of Natural History, Smithsonian Institution, revealed that this species is widely distributed, occurring in Bermuda, along the southeastern coast of the United States as well as throughout the Gulf of Mexico and the Caribbean Sea.

Institutional abbreviations: AMNH, American Museum of Natural History, New York; DMNH, Delaware Museum of Natural History; MCZ, Museum of Comparative Zoology, Harvard University; USNM, National Museum of Natural History, Smithsonian Institution.

Family Naticidae Gray, 1840
Genus *Natica* Scopoli, 1777
Natica (Natica) guesti *new species*
(Figs. 1-11)

Description—Shell of moderate size (to 33 mm), globose, thin but strong; spire angle 111°-136°; protoconch (Fig. 10) of 2¼ whorls, smooth, glossy, straw-colored; transition to teleoconch abrupt, marked by beginning of regular incised furrows; teleoconch with up to 3⅓ smooth, rounded whorls; suture adpressed; axial sculpture of fine growth lines and incised furrows that become pronounced to form fine ribs along suture; umbilicus narrow, deep; funicle small, situated at midpoint of columella; parietal callus reduced, extending along apical ⅓ of columella; aperture large, subcircular; interior glossy, translucent; shell color milky beige, with lighter band below suture; other markings, when present, comprised of spiral bands of brown dots or flammules, one midway between suture and periphery, one just below periphery, and rarely a third one midway between periphery and base; periostracum very thin, straw-colored; operculum (Fig. 6) calcareous, paucispiral; nuclear callus raised; a deep, wide, flat-bottomed groove and 2 raised ribs border periphery; outer surface of operculum pure white; inner surface straw-colored; radular ribbon (Fig. 11) (one examined) taenioglossate, short (0.22 shell height), consisting of 81 rows of teeth; rachidian trapezoidal, with broad attachment area and 2 blunt basal processes; cutting edge tricuspid, central longer than flanking cusps; lateral tooth with complex, hourglass-shaped attachment area, anterior portion giving rise to broad, rounded cutting edge with one large cusp flanked by reduced cusps; inner marginal tooth broad, curved, bicuspid, outer cusp broader, blunter; outer marginal tooth simple, scythe-shaped.

Type material—**Holotype:** USNM 765087, in 201 m, about 40 miles NW of St. Martin, Leeward Islands (18°13′N, 63°19′W) R/V *Oregon* sta. 5914. **Paratypes:** USNM 765077, in 384 m, about 50 miles SW of St. Croix, Virgin Islands (18°14′N, 64°20′W) R/V *Oregon* sta. 2646 (1 specimen); USNM 765079, in 404 m, about 20 miles NNW of Mayaguez, Puerto Rico (18°32′N, 67°09′W) R/V *Oregon* sta. 2659 (1 specimen); USNM 765080, in 210-201 m, about 70 miles SSE of Pascagoula, Mississippi (29°15′N, 88°05′W) R/V *Oregon* sta. 2826 (1 specimen); USNM 765081, in 320-347 m, about 20 miles NNW of Riohacha, Colombia (11°50′N, 73°05′W) R/V *Oregon* sta. 4911 (2 specimens);



FIGS. 1-9. *Natica guesti* new species. **1-5**, Holotype, USNM 765087, trawled in 201 meters, about 40 miles NW of St. Martin, Leeward Islands (18°13'N, 63°19'W) R/V Oregon sta. 5914, 1.5× (Figs. 1-3 whitened with ammonium chloride to enhance sculptural details). **6**, Operculum of holotype, 2.0×. **7**, Paratype, dredged in 174 meters, off St. James, Barbados, C. J. Finlay collection, 1.75×. **8**, Paratype, DMNH 164500, in trap set in 347 meters, 2½ miles off Castle Roads, Bermuda, Lightbourn-Guest Northstar Expeditions, 1.5×. **9**, Paratype, USNM 765082, trawled in 274 meters, about 40 miles E of El Portete, Guajira Peninsula, Colombia (12°17'N, 72°03'W) R/V Oregon sta. 4921, 1.0×.

USNM 765082, in 274 m, about 40 miles E of El Portete, Colombia (12°17'N, 72°03'W) R/V *Oregon* sta. 4921 (2 specimens); USNM 765084, in 320 m, off Bridgetown, Barbados (13°00'N, 59°33'W) R/V *Oregon* sta. 5018 (3 specimens); USNM 765085, in 205 m, off Puerto Obaldia, Panama (8°51'N, 77°25'W) R/V *Oregon* sta. 5734 (1 specimen); USNM 765086, in 296 m, about 20 miles NW of St. Martin, Leeward Islands (18°11'N, 63°15'W) R/V *Oregon* sta. 5913 (1 specimen); USNM 765088, in 165 m, W of St. Lucia, Windward Islands (13°41'N, 60°53'W) R/V *Oregon* sta. 5955 (1 specimen); DMNH 96986, in traps set in 402 m, 2½ miles off Castle Roads, south shore Bermuda, Lightbourn-Guest *Northstar* Expeditions (1 specimen); DMNH 164500 and AMNH 213734, in traps set in 347 m, 2½ miles off Castle Roads, south shore, Bermuda, Lightbourn-Guest *Northstar* Expeditions (7 specimens); MCZ 294668, in 146-183 m, ¾ mile off Castle Rock, Bermuda, Bermuda Biological Station #7 (2 specimens); MCZ 294667, in 421 m, off Puerto Tanamo, Cuba (20°45'N, 75°20'W) *Atlantis* sta. 3375 (1 specimen); C. J. Finlay collection, dredged in 174 m, off St. James, Barbados (1 specimen); J. R. H. Lightbourn collection, in traps set in 340-400 m, 2½ miles off Castle Roads, south shore, Bermuda, Lightbourn-Guest *Northstar* Expeditions (14 specimens); A. T. Guest collec-

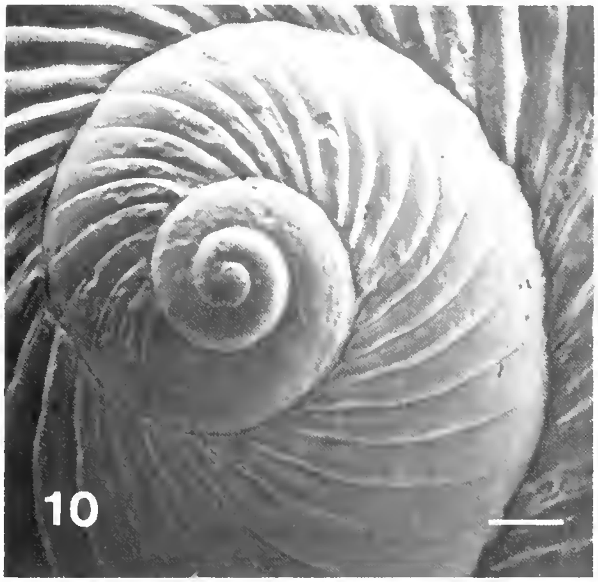


FIG. 10. *Natica guesti* new species, protoconch, scale bar = 500 μm.

FIG. 11. Half row of radular ribbon taken from the holotype, scale bar = 100 μm.

tion, in traps set in 340-400 m, 2½ miles off Castle Roads, south shore, Bermuda, Lightbourn-Guest *Northstar* Expeditions (12 specimens).

Type locality–In 201 meters, about 40 miles NW of St. Martin, Leeward Islands (18°13'N, 63°19'W) R/V *Oregon* sta. 5914.

Remarks–This new species may be distinguished from other western Atlantic naticids by its moderate size, globose shape, small funicle, deep umbilicus and distinctive operculum. *Natica guesti* most closely resembles the Mediterranean species *N. dillwynii* Payraudeau, 1826, from which it differs in being larger, and having a greater spire angle, a less pronounced funicle, fine axial ribs adjacent to the suture, and lacking the 3 or 4 white spiral bands. Opercula of these two species are similar, but the marginal groove is proportionally much broader in *N. guesti*.

N proxima C. B. Adams, 1850, from Jamaica (non Wood, 1848) has a higher spire and proportionately larger funicle. Dall (1889, p. 292) synonymized *proxima* with *maroccana* Dillwyn, 1817.

Although introductions of European species into Bermuda waters have been documented (Abbott and Jensen, 1968), the wide geographic and deep bathymetric ranges of *N. guesti* argue convincingly against it being a recently introduced species.

It was through the intensive investigations of the mollusks of Bermuda by Arthur T. Guest, of Cardinal Hill, Bermuda, that this species came to light, so we take great pleasure in naming this taxon in his honor. The popular, English name for this species may be Guest's Moonsnail.

TABLE 1. Shell measurements of *Natica guesti* (linear measurements in mm) n = 10.

Character	mean	range	standard deviation
shell height	23.02	11.4–32.6	6.98
shell width	22.51	11.6–30.3	6.44
aperture height	17.56	9.4–25.0	5.32
aperture height / shell height	0.83	0.80–0.87	0.02
whorls, teleoconch	2.83	2.3–3.1	0.30
spire angle	119.4°	111°–134°	7.3°

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POPULATION CHARACTERISTICS OF THE PERIWINKLE, *NODILITTORINA UNIFASCIATA*, ON A VERTICAL ROCK CLIFF IN WESTERN AUSTRALIA

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ABSTRACT

Population characteristics of the periwinkle snail, Nodilittorina unifasciata, *were monitored on a vertical rock cliff at Watermans Bay, Western Australia, from Novemeber 1980 to November 1981. During the year the population suffered a massive density decline, from 426/m² to as low as 29/m². Two primary causes of the mortality are hypothesized: post-reproductive mortality of adults in summer and the failure of recruitment in 1981. Density recovered to 62% of its original level by November 1982. Small, medium and large individuals were evenly spread over the vertical area occupied by* N. unifasciata; *there was no segregation by size. Presence of crevices in the rocks was more important to* N. unifasciata *than the open space of the cliff. The snail has a lifespan in this area in which recruits reach reproductive maturity in two years. There is substantial post-reproductive mortality but a portion of the population survives for a third year. Thus, there is an overlap of the reproductive population from one year to the next, preventing genetic isolation between year groups.*

Littorinid snails are common on shallow subtidal and intertidal shores in most regions of the world (Rosewater, 1970). The animals often occur in high densities (thousands per square meter) and are presumably important in energy flow in the environment in which they live. Littorines are surface raspers, scraping microscopic algae from the rock face or plant surfaces (Robertson and Mann, 1982) and converting it into animal tissue available to the higher levels of the trophic system. Despite their apparent importance there are few studies of the level of somatic production by littorinids. Borkowski (1974) examined the productivity of six species in southern Florida and a number of papers have shown population densities and growth of various species (e.g. Bingham, 1972; Borkowski, 1974; Hughes, 1980; Robertson and Mann, 1982).

The dominant littorinid of southern Australia is *Nodilittorina unifasciata* (Gray, 1839)[1] which extends from southern Queensland to North West Cape, Western Australia (Underwood, 1974). Few data are available on the population characteristics of this species in any area of its range. Underwood (1974) included *N. unifasciata* in a study of the reproductive periodicity of 10 common intertidal species in eastern Australia. Black *et al* (1979) recorded densities of 0 to about 40/m² at Rottnest Island, W. A. Branch and Branch (1981) investigated the species in detail in the Sydney area with a view to confirming the presence of intraspecific competition in *N. unifasciata* and its level. The present paper is intended to provide preliminary information on variations in such population characteristics as density, size-frequency, shore height, and biomass at a site in the Perth area of Western Australia.

Materials and Methods

A sampling station was established just south of the fishery reserve at Waterman's Bay, Perth, Western Australia (31°50′S; 115°42′E). The sample area is a small limestone peninsula with a platform extending seaward at a tidal level of 0.4 m. Landward of the platform is a vertical cliff approximately three meters high.

[1]This species has generally been placed in the genus *Littorina* but recent work on the anatomy of Caribbean littorinids by Bandel and Kadolsky (1982) suggests that it should be transferred to *Nodilittorina*.

Tides are a mixture of semidiurnal and diurnal with a maximum range of 0.3 to 1.3 m; levels are generally higher in winter than summer. They can be altered substantially by atmospheric conditions (Hodgkin and DiLollo, 1958). The Waterman's Bay site is exposed to wave action from the open sea, though this is dampened somewhat by a subtidal reef several kilometers offshore. Wave action is greater in winter than summer.

Samples were made on the cliff at approximately monthly intervals from November 1980 to November 1981, except for April; a follow-up sample was made in November 1982. On each occasion four transects were sampled. The transects, which were 20 cm wide and divided into quadrats 15 cm high, extended up the cliff from the platform surface to the maximum height of the *N. unifasciata* population. To determine size-frequency and shore height characteristics all individuals of *N. unifasciata* in each quadrat were counted, measured to the nearest 0.1 mm in shell length with calipers, and returned to the area. For the dry weight biomass determination 50 individuals covering the entire size range of *N. unifasciata* were measured to the nearest 0.1 mm, decalcified in 7% hydrochloric acid, washed in freshwater, dried to constant weight at 60°C, and weighed to the nearest 1 mg on a Sartorius microbalance. The lengths and weights were converted to logarithms and a linear regression calculated. The resulting equation relating shell length to dry tissue weight was then used with the size-frequency and density data to estimate monthly biomass.

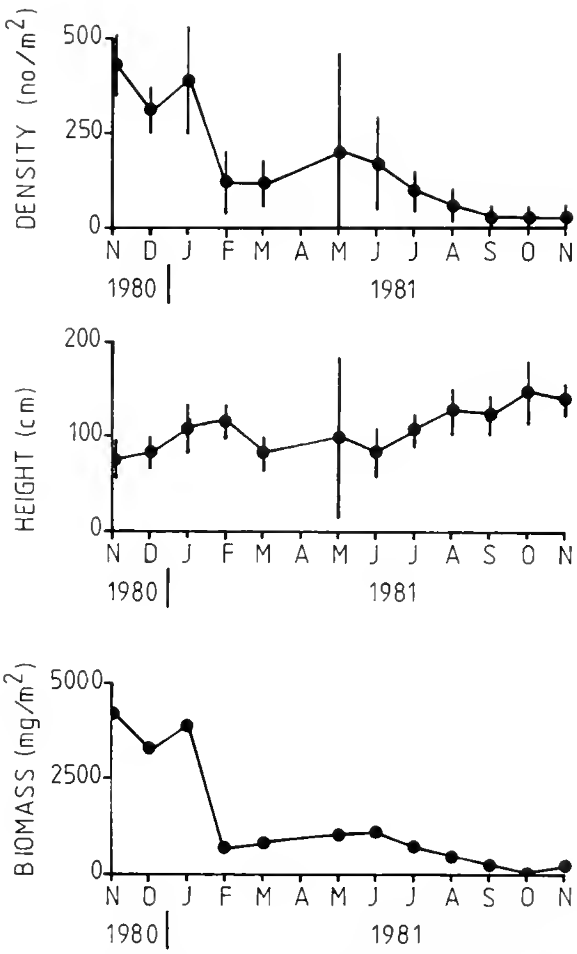

FIG. 1. Population characteristics of *Nodilittorina unifasciata* on a vertical rock cliff at Watermans Bay, Western Australia from November 1980 to November 1981. **1a.** Density. **1b.** Shore height. **1c.** Dry weight, shellfree biomass. Vertical bars are standard deviations.

Results

The highest densities were recorded at the beginning of the study (Fig. 1a), with 426/m² in November 1980. Density remained high until January 1982 then declined sharply to 122/m² in February. There was some recovery of the population in May as new recruits entered but density was still only 199/m², half of the initial value. Density declined steadily after May and ranged from 29 to 32/m² during the period of September to November 1981. When density was checked in November 1982 it had recovered to 263/m², still only 62% of the initial value.

L. unifasciata inhabited the shoreline from the top of an algal zone 40 cm above the platform to a maximum height of 240 cm above the platform. Figure 1b shows the changes in mean height of the population over the year sampled. The mean height was 75 cm above the platform in November 1980 and moved up steadily to 118 cm in February. As new recruits entered the population in May and June the mean shore height dipped temporarily to 83 cm but increased steadily during the winter to 147 cm by October. There was no clear seasonal variation in the shore height occupied by the population, but during the winter a filamentous green algae grew on the lower part of the cliff. Areas of algal growth were avoided by *N. unifasciata*. Newly metamorphosed individuals seemed to settle initially over the entire vertical range of

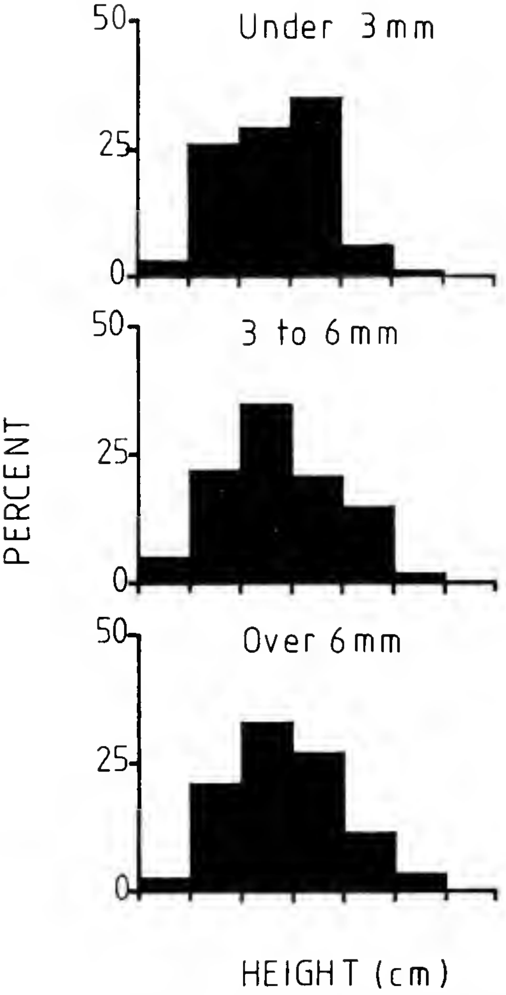

FIG. 2. Shore heights occupied by three size classes of all individuals of *N. unifasciata* collected at Watermans Bay, Western Australia, from November 1980 to November 1981.

N. unifasciata with somewhat larger numbers settling lower on the shore. However the vertical distribution of the recruits soon matched that of the population as a whole. Figure 2 compares the vertical distribution of all *N. unifasciata* in three size classes collected during the study: less than 3.0 mm (mean height 88.7 ± 32.8 cm); 3.0 to 6.0 mm (mean height 90.3 ± 48.6 mm); and greater than 6.0 mm in shell length (mean height 93.1 ± 47.1 cm). There was no statistically significant difference between the mean heights of the three groups (t-test, 0.05 level).

Figure 3 plots the relationship between shell length and dry tissue weight on a log/log basis. The equation is a straight line of Y = −4.61 + 2.68 × (r^2 = .93). The biomass each month is shown in figure 1c, and closely parallels density (Fig. 1a). Biomass was highest (4.2 g/m²) in the sample of November 1980 and remained high until January 1981. In February biomass declined sharply to 0.7 g/m². It increased slightly to 1.0 g/m² in June due to the influx of recruits into the population but then declined to a minimum of 0.3 g/m² in October. The mean biomass during the year examined was 1.4 g/m². This was concentrated in the first half of the period, with a mean biomass of 2.3 g/m² from November to May and only 0.5 g/m² in June to November.

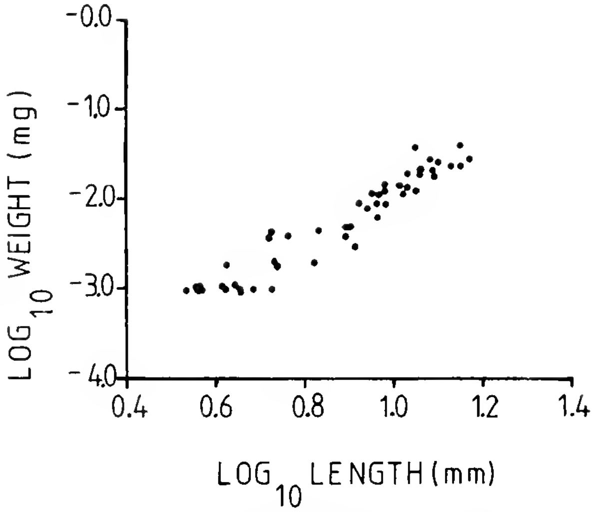

FIG. 3. Log/log graph of shell length versus shellfree, dry weight of *Nodilittorina unifasciata* collected at Watermans Bay, Western Australia. Y = −4.61 + 2.68 × (r^2 = 0.93).

Figure 4 shows the size-frequency curves for each month examined. Recruits to the population were first seen at a length of 1.2 mm. Individuals smaller than 2 mm were present in all months except August and September. The peak number of small individuals was recorded in May and June. Changes in the size-frequency curves from May to November can be used to estimate growth of the juveniles. Their mean size was 3.0 mm in May, 3.7 mm in August and 4.6 mm in November. The curve for November 1981 is distinctly bimodal, indicating that there are at least two, and possibly three, year classes in the population. In contrast to the November 1981 graph the plot for November 1980 is unimodal with large numbers of small individuals spread over the range of 2 to 8 mm. This does not necessarily contradict the suggestion that *N. unifasciata* lives two years but does suggest

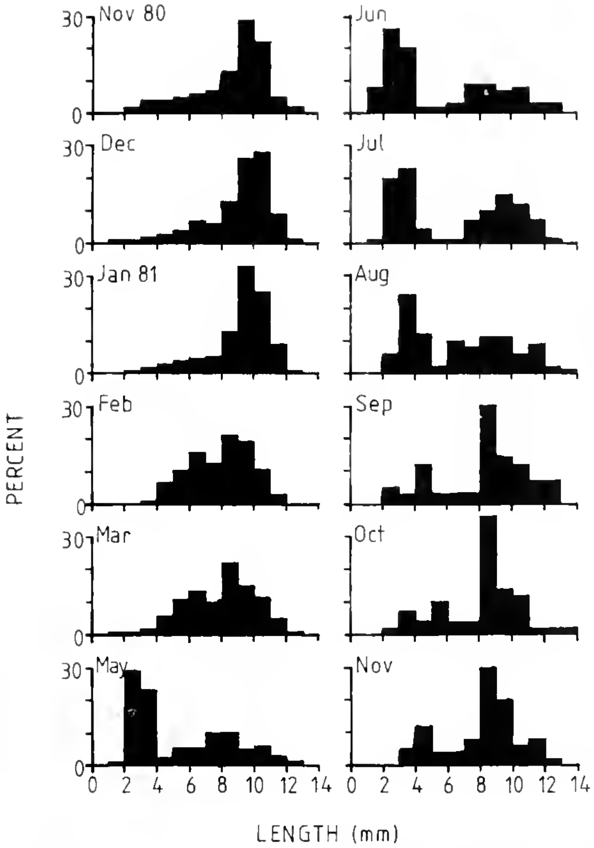

FIG. 4. Size-frequency graphs of *Nodilittorina unifasciata* collected at Watermans Bay, Western Australia, from November 1980 to November 1981.

that 1979 was a better year for recruitment and subsequent growth than 1980.

When sampling began in November 1980 the study site was at the southern end of a small peninsula. Beginning the following April fall storms washed sand away from the southern end of the peninsula, exposing an underlying rock platform. *N. unifasciata* began to migrate southward onto the expanding platform. The migrating individuals were 8 mm or longer, and were not simply small juveniles which had settled on the platform. The population of *N. unifasciata* on the platform was surveyed in August 1981 when the platform reached its greatest width of 50 m. For the survey transects ropes were laid up the shore every 5 m on the platform and all *N. unifasciata* 30 cm each side of the rope counted. A similar series of transects was made on the vertical cliffs of the peninsula. An estimated 5500 snails had migrated onto the platform, 3.1% of the total on the cliff of 171 000 and 7.8% of the population longer than 8 mm. As summer approached the returning sand covered the platform adjacent to the peninsula first then covered up the platform further south. This killed all, or nearly all of the *N. unifasciata* which had migrated onto the platform.

Discussion

During the brief period of this study, the *N. unifasciata* population declined in density by 93%. The resurvey one year after the study showed that the population had recovered to 62% of its initial level. The most dramatic mortality occurred in January-February. While the source(s) of this mortality are not obvious several possibilities can be discussed. Predation by other animals is one possible source. *N. unifasciata* lives high on the shore where the population is never covered by water, eliminating the possibility of predation during high tide by fish. The predatory whelk *Thais orbita* (Gmelin, 1791) is present on the lower part of the cliffs in small numbers. The species is a heavy predator of limpets (Black, 1978) but occurs too low on the shore to be a major predator of *N. unifasciata*. Sea birds, particularly oyster catchers, have been observed on the platform feeding on molluscs, but never on the cliff. In addition dead shells washed up on the beach showed no signs of predation. This suggests the possibility of animal predation can be discounted as a major source of the mortality. A similar conclusion was reached by Branch and Branch (1981). Human predation could have occurred but was never observed during the study period. Hodgkin (1959) showed that during the summer coastal platforms could remain dry throughout the day, or even for several days, when atmospheric high pressure systems caused continuous easterly winds. The easterlies come off the hot desert areas of central Australia, often raising temperatures to 40°C or more. These periods of high temperatures and continuous exposure are times of catastrophic mortalities on the platforms. This could have caused the summer mortality in *N. unifasciata*. However, the mortality was concentrated amongst the largest individuals of the population suggesting that post-reproductive mortality was the primary cause. The size-frequency graphs changed markedly between January and February. In-

dividuals 9 mm or more in shell length were 68% of the population in January but only 33% in February; the large individuals accounted for 81% of the decline which occurred between the January and February samples.

Density increased in May and June as recruits entered the population but declined steadily in subsequent months as many of the young individuals died. Recruitment during 1981 was largely a failure, the causes of which are not known. Recruitment was better in 1982 as evidenced by the return of the population to a density of about 62% of its original level. Thus there are substantial year to year variations in the population density of *N. unifasciata,* which can be as high as at least one order of magnitude.

I originally expected recruits to be at the lowest shore levels then move up vertically as they grew. Such a pattern has been found in other gastropods (Edwards, 1969) including littorinids (Robertson and Mann, 1982). Branch and Branch (1981) found the lowest mean size was in the middle of the range of *N. unifasciata.* There was an initial tendency for small individuals to be at low shore levels, but this concentration was rapidly dissipated and was not statistically significant. The more important small scale determinant of distribution within the main portion of the vertical area inhabited by *N. unifasciata* was the presence of crevices in the rocks. *N. unifasciata* were concentrated in the crevices during the summer and were inactive. They were scattered about the entire rock face during winter and were actively moving about. During winter temperatures were lower and the rock face was constantly wetted by wave action. The number and type of crevices as areas of refuge for *N. unifasciata* during the summer might be a factor setting an upper limit on the population as was shown for *Littorina rudis* and *L. neglecta* by Raffaelli (1978). Branch and Branch (1981) demonstrated intraspecific competition in *N. unifasciata.* This occurred at densities several times greater than those recorded at Watermans, and intraspecific competition was probably not important in this study.

Because of the decline in the population over the year no attempt was made to estimate somatic production. The six species of littorinids examined by Borkowski (1974) had production to biomass ratios ranging from 1.3 to 4.7. The mean biomass of *N. unifasciata* at Waterman's Bay was 1.4 g/m^2. If the P:B ratios of Borkowski are used, a dry tissue production of 1.8 to 6.1 g/m^2/year can be estimated for *N. unifasciata* during 1980-81. This figure must be regarded as preliminary as it would vary considerably depending on the population level. Borkowski (1974) demonstrated that spawn production is a significant component of secondary productivity in littorinids and may substantially exceed somatic production. This aspect of production was not investigated for *N. unifasciata.*

The data presented here suggest that *N. unifasciata* has a lifespan of at least two years. Recruits entering the population, predominantly in May, reached 4.6 mm by November. If growth continued at the same rate the animals would be adults during their second summer of life and would spawn then. Despite the substantial post reproductive mortality found in summer at least some individuals survived to their third year. This lifespan is within the range of other littorinids demonstrated by Borkowski (1974) and Robertson and Mann (1982). The continuance of a portion of the reproductive population into another year is important as it prevents the development of two reproductively isolated year groups alternately spawning in the same area.

Acknowledgments

I thank Dr. D. S. Hancock of the Western Australian Department of Fisheries and Wildlife for access to the fishery reserve.

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CHANGES IN THE NAIAD FAUNA OF THE CUMBERLAND RIVER BELOW LAKE CUMBERLAND IN CENTRAL KENTUCKY

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ABSTRACT

A survey for live mussels was conducted below Wolf Creek Dam, miles 460.8 to 393.2, on the Cumberland River, Kentucky, on 21-23 October 1982. The purpose of the study was to determine if mussel recruitment had taken place following completion of the dam in 1952. The only live bivalves found were the Asian clam, Corbicula, *and two unionid mollusks,* Cumberlandia monodonata *and* Cyclonaias tuberculata. *Physical and chemical factors which include very cold (less than 20° throughout the year), nutrient-poor release waters from Lake Cumberland plus turbulent flow and fluctuating water levels contribute to conditions unsuitable for maintenance of reproducing populations of naiad mollusks in this portion of the river.*

Wolf Creek Dam, at mile 460.9 on the Cumberland River in south-central Kentucky (Fig. 1), was fully completed in August 1952 and resulted in the creation of Lake Cumberland, a 50,250-acre (at maximum pool) body of water. Wolf Creek Dam releases water into the Cumberland River which is free-flowing for about 50 miles until just past the town of Burkesville, Kentucky, where it becomes influenced by Cordell Hull Reservoir located near Carthage, Tennessee. At the dam is a power station capable of generating 270,000 kw with six generators. Water is taken from Lake Cumberland by way of six conduits; the inlets are located below the thermocline in the lake. As a result, the station operates with cold, hypolimnetic waters during all times of the year. Typically the power plant functions only during periods of peak energy demand, from about 7 a.m. until 12 p.m. during each 24-hour period. During this routine shutdown period, virtually no water passes from the lake into the river, and water levels immediately below the dam decline by 5 feet or more by 7 a.m.

On 20 October 1982 at 12 midnight, the Wolf Creek Power Station was closed for maintenance; electricity generation was suspended for a total of 150 hours and resumed on 26 October at 6 a.m. During this time water levels below the dam declined by approximately 6 ft. and water depth and velocity were reduced in the river past Burkesville. The brief low-water period in this section of the Cumberland River provided an excellent opportunity to search for freshwater mussels, and document the effects of dam

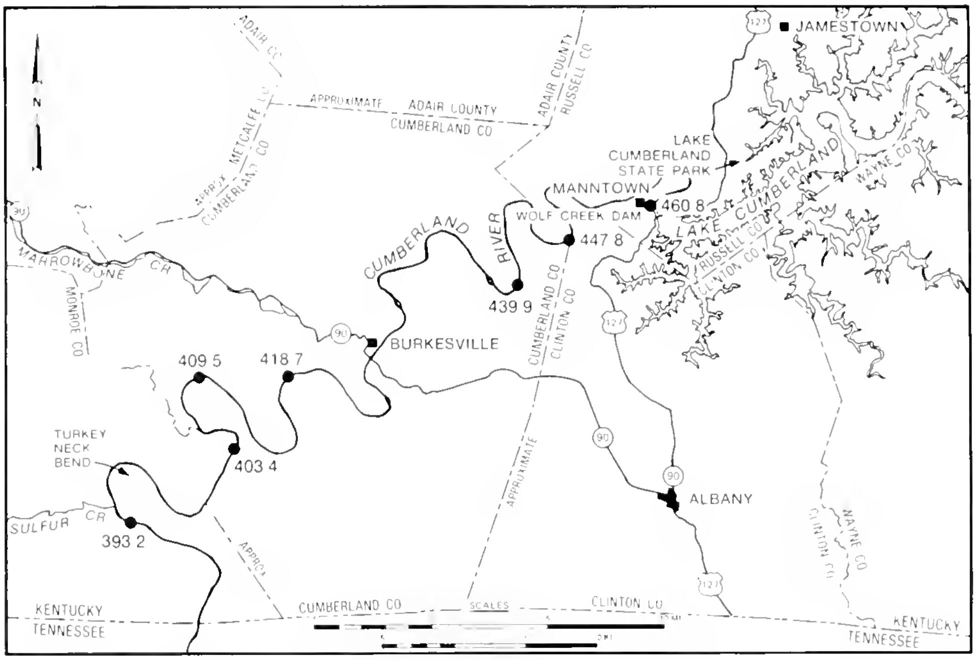

FIG. 1. Sites Sampled for Mussels on the Cumberland River, Russell, Cumberland, and Monroe Counties, Kentucky, on 21-23 October, at river miles shown.

closure on the native naiad fauna.

The unionid fauna of this area was documented by Wilson and Clark (1914) and collected most recently by Neel and Allen (1964) in 1948-49 just prior to dam closure. In 1961 Stansbery (1969) collected naiad mollusks at Cumberland Falls, and compared the results of his work with the two sets of previous workers. A general discussion of the effects of storage release reservoirs can be found in Pfitzer (1954) who collected snails (no mussels), aquatic insects, *Gammarus*, and fish in the tailwaters of rivers in the Tennessee Valley.

Methods

A total of seven sites below the dam on the Cumberland River were surveyed for mussels on 21-23 October 1982. Sampling equipment used during the survey included modified garden rakes, a handheld basket dredge, a 2-ft wooden brail bar equipped with handmade hooks, and viewing buckets. Intensive searching was conducted at areas where it was judged that mussels would most likely occur; i.e. below tributary streams, in mud and gravel/sand substrate, and around and under medium to large-sized rocks.

Results and Discussion

Two live mussels were collected on the Cumberland River in the study area, the Spectacle Case (*Cumberlandia monodonta*) and the Purple Pimpleback (*Cyclonaias tuberculata*), which were found at miles 409.5 and 403.4, respectively. These mussels were lying on, not buried in, the substrate in water that was 50 cm deep or less. The umbones on *C. tuberculata* were deeply eroded, and the periostracum on *C. monodonta* were heavily worn, indicating the erosive action of turbulent water in the river. These specimens were found some distance downriver of the dam; i.e., 60.3 and 57.4 river miles, respectively.

The Asian Clam (*Corbicula fluminea*) was the only other live bivalve collected during the survey. This species became progressively more common as one proceeded downriver of the dam; for example, below the mouth of Sulfur Creek (river mile 393.2) a dozen or more individuals were obtained. Although fairly common here, numbers at this site were much fewer than $1.0/m^2$. All *Corbicula* collected were very small (i.e., less than 3.0 cm long, with average weight about 4.0 grams), and the umbones were

deeply eroded.

Because the release water from the dam is hypolimnetic, water temperatures in the summer do not exceed 20°C (Fig. 2). Evidently, the low water temperatures inhibit mussel recruitment in this portion of the river. In a study of the Pigtoe Mussel (*Pleurobema cordatum*) in Alabama, for example Yokley (1972) found that embryo development did not occur until water temperatures had achieved 23°C. On the other hand, mussel recruitment can occur in cool waters. Zale and Neves (1982) studied four lampsiline species in Big Moccasin Creek, a third-order tributary of the Holston River in southwestern Virginia. Spawning times and temperatures ranged from July to late August and from 16.4°C to 25.8°C, respectively; however, *Medionidus conradicus* glochidia were collected with drift nets during winter months when temperatures were above 5°C and juvenile recruitment for the species occurred throughout the year (Zale 1980).

Neel and Allen (1964) during their survey in 1948-49 identified 39 species from the Cumberland River below Wolf Creek Dam. Three species (*Elliptio dilatatus*, *Ptychobranchus fasciolaris*, and *Lampsilis ovata*) were considered abundant. *Cyclonaias tuberculata* and *Cumberlandia monodonta* were both judged to be rare; live specimens of the latter species were not found in this stretch of the river. *C. monodonta* was taken only from sheltered areas near large rocks. This species avoids the stress of turbulent water and is usually taken from firm mud, protective cracks between boulders, or beds of vegetation (Stansbery 1966).

Conclusion

Turbulent water, fluctuating water levels, and temperatures which remained below 20°C throughout the year are not conducive to mussel recruitment below Wolf Creek Dam. Although previous workers found a diverse assemblage of species, this survey yielded only two live unionids. When the dam was completed, unionid recruitment essentially ceased and existing mussels were gradually lost because of adverse conditions, predation, or natural mortality. The two live mussels collected in October 1982 evidently had survived since dam closure. The *Corbicula* taken in several locations were undoubtedly the product of natural recruitment.

Acknowledgments

The authors appreciate the support and information provided by Mr. H. T. Sansing, Chief, Water Quality Section, US Army Engineer District, Nashville. Funds to conduct this work were provided by the Nashville District Office.

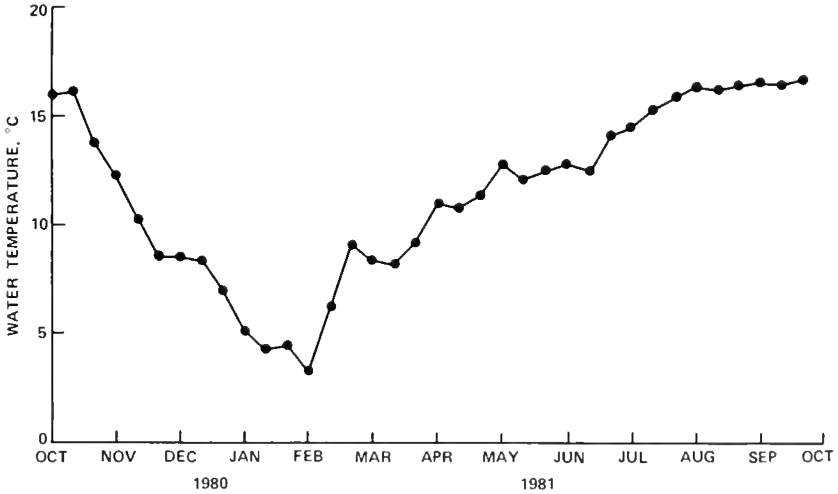

FIG. 2. Water Temperatures at Burkesville in Russell County, Kentucky, river mile 422.8, from 1 October 1980 to 30 September 1981 (from US Geological Survey 1982). Each point is the mean of from 8 to 11 values.

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FRESHWATER MUSSELS (BIVALVIA: UNIONIDAE) OF HORSE LICK CREEK, ROCKCASTLE RIVER, KENTUCKY

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ABSTRACT

A survey of the mussel fauna of Horse Lick Creek, a 26.2-km tributary of the Rockcastle River, was conducted from the fall of 1982 through the summer of 1983. Twenty-two species of mussels and Corbicula fluminea *were recorded, including the federally endangered* Villosa trabalis *and state-endangered* Pegias fabula. *The stream appears to be one of the last refuges for several Cumberlandian species in Kentucky.*

Horse Lick Creek originates in northeastern Jackson County, Kentucky, approximately 300 meters east of the Rockcastle-Jackson County line, and flows southward 26.2 km (16.3 miles) to join the Rockcastle River near the boundaries of Jackson, Laurel and Rockcastle Counties (Fig. 1). The creek is a low-gradient, fourth order stream, characterized by extensive, deep pools with intermittent, shallow riffles (Carter and Jones, 1969). Water chemistry is affected by limestone deposits, interspersed with shale, siltstone and sandstone bedrock (Harker *et al.*, 1979, 1980).

Human impacts such as agriculture, logging and mining are limited within the Horse Lick Creek drainage basin, which is 65% forested and almost totally contained in the Daniel Boone National Forest. Although roughly 10% of the Clover Bottom watershed (the largest tributary to Horse Lick Creek) is disturbed by strip mining (Harker *et al.*, 1980), Horse Lick Creek is considered one of the highest quality streams in the upper Cumberland River drainage.

Several mussel surveys have been conducted on the Rockcastle River at Livingston, Kentucky, downstream of Horse Lick Creek (Williamson, 1905; Wilson and Clark, 1914; Blankenship and Crockett, 1972). Blankenship (1971) reported *Pegias fabula* (Lea) at two sites in the lower 3.1 km of the creek, and Harker *et al.* (1980) collected 12 mussel species from Horse Lick Creek during their survey of the upper Cumberland River basin. This study was initiated in the fall of 1982 to develop a list of mussel species in Horse Lick Creek.

Methods and Materials

Shells were handpicked from the stream bot-

tom using a waterscope; some voucher specimens were taken. The stream banks provided a paucity of shells. Many sections of the creek were visited, and collecting stations chosen. The entire creek below the KY 1955 bridge (Fig. 1) was floated and/or walked to locate existing mussel beds. Designated stations were sampled for a period of 2.5 to 5.5 man-hours. At each station, qualitative observations were made on habitat and mussel abundance.

Scientific names follow those of D. H. Stansbery of the Ohio State Museum of Zoology, where voucher specimens have been deposited. Some specimens have also been retained in the author's collection.

Collecting Stations

Mussels were collected at eight stations on Horse Lick Creek and one site (Station 2) on Clover Bottom (Fig. 1).

Station 1 – The 6.4 km of stream from the KY 1955 bridge downstream to Clover Bottom were float-surveyed by two individuals.

Station 2 – This site is on Clover Bottom, about 400 m upstream from its mouth. The station is 200 m in length, 6 to 10 m wide, and varies in depth from 10 to 60 cm.

Station 3 – Located 200 m below the mouth of Clover Bottom at Horse Lick Creek Mile (HLCM) 9.4 (15.1 km). The site is 100 m long, and shallow (30-45 cm). Stream width is approximately 10 m.

Station 4 – This 75 to 80 m section is 12 to 15 m wide, and of variable depth. It is situated at HCLM 5.5 (8.9 km), about 400 m above the mouth of Raccoon Creek. The upper riffle included a samll center shoal with *Justicia* sp.

Station 5 – Located approximately 650 m below the mouth of Raccoon Creek, and 100 m downstream from a concrete low-water bridge. Stream width ranges from 10 to 15 m.

Station 6 – Situated at a ford, HLCM 2.0 (3.2 km), extending 100 m upstream of the ford. The creek here is approximately 12 m wide, deeper at the upper end, and bordered by several small beds of *Justicia* sp.

Station 7 – 3.0 to 3.1 km above the mouth (HLCM 1.9), this station is a long (100 m), shallow (10-30 cm) riffle stretch. Width varies from 5 to 15 m as the stream winds around and through several shoals and fallen trees.

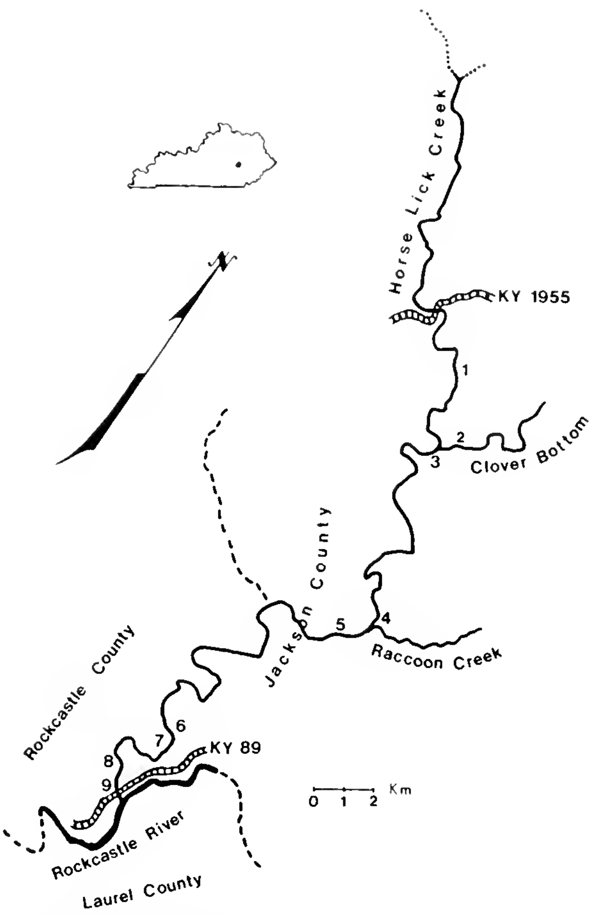

FIG. 1. Collecting stations along Horse Lick Creek. Localities are identified in text.

Station 8 – Located about 0.5 km upstream from the mouth (HLCM 0.3). This site is 80 m in length, and changes in habitat composition, noticeably, from a shallow upper riffle to a deeper run, with an exposed sandbar along the mid-section. Stream width varies from 5 to 10 m.

Station 9 – Located 0.2 km above the confluence of Horse Lick Creek and the Rockcastle River. The stream width is a fairly constant 10 m.

Results and Discussion

A total of 22 species of naiades and the Asian clam, *Corbicula fluminea*, were collected in Horse Lick Creek (Table 1). Of the 22 species, 18 were collected live. *Villosa taeniata punctata* was the most common mussel species in this stream. *Medionidus conradicus*, although not as

Table 1. Checklist of mussel species found at stations along Horse Lick Creek, 1982 – 1983.

Mussel Species	Station No. 1	2	3	4	5	6	7	8	9
Actinonaias ligamentina carinata (Barnes, 1823)						X			
Actinonaias pectorosa (Conrad, 1834)				X		X		X	*
Alasmidonta marginata Say, 1818					X		X		
Alasmidonta viridis (Rafinesque, 1820)	X		X	X	X		*		
Amblema plicata plicata (Say, 1817)									X
Elliptio crassidens crassidens (Lamarck, 1819)				*					
Elliptio dilatata (Rafinesque, 1820)				X	X	X	X	X	*
Lampsilis fasciola Rafinesque, 1820	*		*	*	*	*	*		*
Lampsilis ventricosa (Barnes, 1823)				X	X	X		X	
Lasmigona costata (Rafinesque, 1820)				X	X	*	*		
Ligumia recta (Lamarck, 1819)				X					
Medionidus conradicus (Lea, 1834)	X	X	X	X	X	X	X	*	*
Pegias fabula (Lea, 1838)			X	*	X	X	X		*
Pleurobema oviforme (Conrad, 1834)					*		*		
Pleurobema sintoxia (Rafinesque, 1820)									X
Ptychobranchus fasciolaris (Rafinesque, 1820)				X	X	X	*	X	X
Ptychobranchus subtentum (Say, 1825)							*		
Strophitus undulatus undulatus (Say, 1817)					X				
Toxolasma lividus lividus (Rafinesque, 1831)				X	X	X	*		
Villosa iris (Lea, 1829)						X	*	X	*
Villosa taeniata punctata (Lea, 1865)	X		*	X	X	X	X	X	*
Villosa trabalis (Conrad, 1834)				X		X		*	
Corbicula fluminea (Müller)				X	X	X	X	X	*
Total	4	1	5	15	14	14	15	9	12

* Shells only

X Live specimens

abundant, was found at every station. Other naiades that were relatively common included *Alasmidonta viridis* (especially in upstream sections), *Elliptio dilatata*, *Ptychobranchus fasciolaris*, and *Lampsilis ventricosa*. Many freshly dead valves of *Lampsilis fasciola* were collected but no live individuals were found. Fallo (*pers. comm.*), however, reported a live specimen at Station 6 following completion of this survey. The following species were uncommon in Horse Lick Creek: *Actinonaias ligamentina carinata*, *Alasmidonta marginata*, *Amblema plicata*, *Elliptio crassidens*, *Pleurobema sintoxia*, *Ptychobranchus subtentum* and *Strophitus undulatus*.

Villosa trabalis, a federally endangered species (U.S. Fish and Wildlife Service, 1982), has been reported extirpated from most of the Cumberland River drainage in Kentucky (Clarke, 1983). This species was found live at stations 4 (7 specimens) and 6 (3 specimens), and freshly dead specimens were collected at station 8. Live mussels were located in sandy habitat immediately above or on the edge of riffles, where the current was slower.

Six live specimens of *Pegias fabula*, designated as endangered in Kentucky by the Kentucky Academy of Science (Branson *et al.*, 1981), were observed at stations 3, 5 and 6. Freshly dead valves of this species were also collected at stations 4, 6, 7 and 9. Blankenship (1971) found several live individuals at a site near station 7 on Horse Lick Creek, while

Harker *et al.* (1980) reported a live specimen approximately 100 m upstream from station 5. Little is known about the habitat preferences of *Pegias fabula.* Blankenship (1971) and Starnes and Bogan (1982) reported individuals laying on or imbedded in the substrate. In this study, specimens were found laying on the substrate, buried in the gravel and sand substrates of pools and riffles, and beneath large rocks (20-50 cm diameter).

The occurrence of *Pleurobema oviforme, Ptychobranchus subtentum,* and *Toxolasma lividus* in Horse Lick Creek is also noteworthy. The first two species are listed as threatened in Kentucky, and the latter is of special concern (Branson *et al.*, 1981).

Alasmidonta viridis appeared to prefer sandy substrate in slower currents. *Ptychobranchus fasciolaris* was usually collected in the slackwater immediately above a riffle. *Medionidus conradicus* seemed to favor fast riffles, but also occurred in high densities under large rocks (20-50 cm diameter).

This survey indicates that Horse Lick Creek contains a diverse and healthy assemblage of mussels, especially for a stream of its size. The scarcity of live individuals near the mouth (station 9) might be attributed to sampling difficulty due to depth, or to the presence of a red precipitate along the banks, possibly iron ocher from a local coal mine.

Horse Lick Creek appears to be one of the few remaining refuges for several Cumberlandian species of mussels in Kentucky, including *Villosa trabalis* and *Pegias fabula.* Adverse impacts to the watershed by human intervention appear minimal at this time. The author urges that steps be taken to insure the future integrity of this stream in order to preserve the few remaining endangered species.

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EFFECTS OF DENSITY AND SAMPLING TIME ON THE GROWTH OF THE HARD CLAM, *MERCENARIA MERCENARIA*, PLANTED IN PREDATOR-FREE CAGES IN COASTAL GEORGIA

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ABSTRACT

Hard clams, Mercenaria mercenaria *(Linné), were planted in predator-free cages on an intertidal sandflat at Cabbage Island at densities of 509, 1009, 2018 and 3027/m². Replicate plots per density were sampled monthly and seasonally, with clams at all four densities sampled seasonally growing significantly greater (analysis of variance ∝ = 0.05) in shell length than those sampled monthly and within the same time period. The seasonally sampled cage was lost after 6 months. Clams planted at the lowest density and sampled monthly reached commercial size (44 mm) in 16 months with 52% of the clams being legal size. After 19 months, 83% of the clams at 509 m² had obtained legal size as compared to 57, 13 and 3% for the clams grown at 1009, 2018 and 3027/m². Overall clam survival increased from 77% after the first month to ≥ 99% three months later, and remained greater than 99% throughout the remainder of the experiment. Survival of clams less than 18 mm in shell length is dependent upon the monthly removal of newly metamorphosed crabs from within cages.*

The hard clam, *Mercenaria mercenaria* (Linné), represents a new and potentially important fishery for the State of Georgia. Clamming is presently a winter activity in Georgia performed by crabbers during their slack season. Thus it is viewed primarily as a potential supplement to the blue crab, *Callinectes sapidus* (Rathbun), fishery in Georgia.

The coastal waters of Georgia contain approximately 450,000 acres of salt marsh much of which is pollution-free and maintains sizable shellfish populations. As more northern waters are closed to shellfishing, due to pollution (National Marine Fisheries Service, 1977), the potential opportunity for utilizing the coastal waters of Georgia for culturing shellfish increases.

Previous hard clam density studies (Manzi *et al.*, 1980; Eldridge *et al.*, 1979; Godwin, 1968) utilized larger-size seed clams (11 to 26 mm) planted at densities up to 3040/m² and only Eldridge *et al.* (1979) maintained initial densities (290, 869, and 1159/m²). The purpose of this study is to determine the feasibility of planting smaller-size and less expensive seed clams (6 mm) at high densities in predator-free cages in the coastal waters of Georgia.

Methods

Two cages (1 × 1 × 0.5 m) constructed of 3-mm-mesh vexar plastic attached to a frame of 13-mm steel reinforcement rods were divided into nine compartments (0.11/m²). Cages were buried to a depth of 0.25 m in May 1982 on an intertidal sand flat at Cabbage Island, Georgia (Fig. 1). In June 1982, 6-mm seed clams supplied by Aquaculture Research Corporation, Dennis, Massachusetts, were planted at the following replicate density per cage: 56, 111, 222 and 333 per 0.11/m² or the equivalent to 509, 1009, 2018 and 3027/m², respectively. The center compartment of each cage was seeded with approximately 500 clams used as replacements for dead clams. A third cage was stocked with 2,000 clams to be used as replacements.

Cage I was sampled monthly while Cage II was sampled seasonally. In Cage I, clams, crabs and sediment to a depth of 10 cm were sieved through a 5-mm mesh screen. Clams were counted, a subsample (N = 70) measured for shell

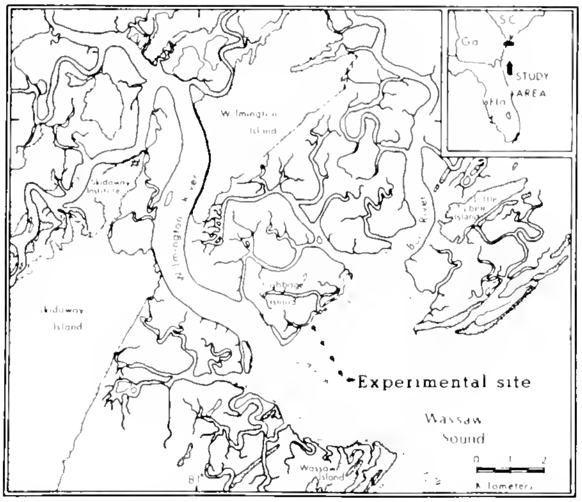

FIG. 1. Map of Wassaw Sound showing experimental study sites.

length (longest possible measurement, i.e., anterio-posterior), additional clams added if needed and returned to their respective compartments. Crabs were identified to species, measured for carapace width and discarded. Cage II was sampled as above, but seasonally; however, the top cm of sediment was sieved monthly to remove newly set crabs (blue crabs, *Callinectes sapidus* Rathbun, and/or mud crabs, *Panopeus herbsti* Milne-Edwards). Cage I was sampled seasonally beginning January 1983, since monthly clam survival had obtained and remained at approximately 100% for several months.

Results

Clam growth and survival in Cage II were high until the cage washed out during a severe storm in January 1983. Clams grew from a mean shell length of 6.1 to 28.3 mm in 6 months (Table 1) or at a rate of 3.7 mm per month. Growth rates are given in Figure 2. No differences in final size or in percent survival between densities (ANOVA α = 0.05) occurred. Clam survival increased with time and growth from 75 to 87% (Table 1).

In Cage I (sampled monthly) clams grew from a mean shell length of 6.1 to 49.7 mm in 18 months (Table 2); however, differences in growth between all densities (ANOVA α = 0.05) occurred in September 1983, 14 months after planting. By September 1983, 52, 31, 4 and 0% of the clams planted at 509, 1009, 2018 and 3027/m², respectively had reached the legal size

TABLE 1. Growth in mm and percent survival of hard clams planted at densities of 509, 1009, 2018, and 3027/m² and sampled seasonally on an intertidal sandflat at Cabbage Island, Georgia.

	September 1982		December 1982	
No. m^{-2}	$\bar{x}$ shell length in mm	percent survival	$\bar{x}$ shell length in mm	percent survival
509	18.1	100.0	29.5	100.0
509	19.0	71.4	29.4	100.0
1009	17.1	95.5	28.1	100.0
1009	18.0	100.0	30.4	100.0
2018	18.6	90.1	27.4	100.0
2018	17.7	64.4	27.1	99.5
3027	17.2	93.1	25.3	100.0
3027	18.9	34.2	29.1	42.9
Average Shell length	18.1		28.3	
Overall percent survival		74.8		86.8

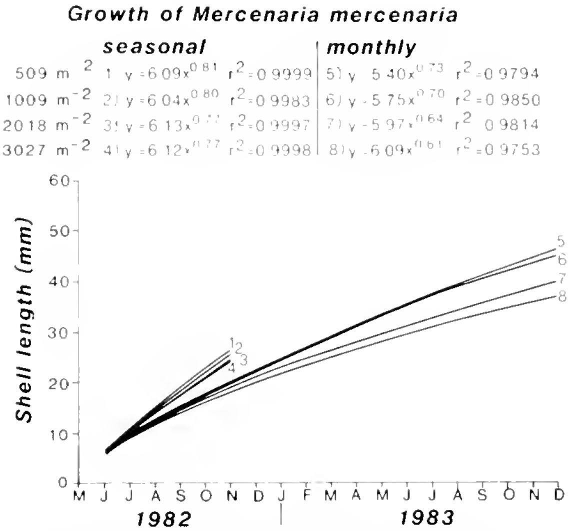

FIG. 2. Growth curves of hard clams planted at different densities and sampled monthly and seasonally. Y = shell length in mm and x = time in months.

limit of 44.4 mm shell length proposed for Georgia (Walker, 1984). By December 1983, 83, 57, 13 and 3% of the clams planted at 509, 1009, 2018, and 3027/m² respectively, had obtained this size. Overall clam survival increased from 77% in July to > 99% after 4 months (Table 3). Overall clam survival was ≥ 99% throughout the remainder of the experiment.

Differences in shell length for equivalent densities between monthly and seasonal cages (ANOVA $\propto$ = 0.05) occurred. In September 1982, clams sampled seasonally had grown approximately 29% greater in shell length (3.7 mm/m¹) than those of equivalent densities but sampled monthly (2.8 mm/m¹). By December 1982, the difference in shell length between cages sampled monthly and seasonally was 20% and significant (ANOVA $\propto$ = 0.05)

Discussion

Optimum seeding density for the hard clam has yet to be determined. Eldridge *et al.* (1979) planted seed clams (13 mm) and maintained densities of 290, 869 and 1159/m² in cages in the coastal waters of South Carolina. Clams at the lower density reached commercial size (44 to 45 mm) in 19 months after planting with clams at the highest density taking an additional 12 months to obtain this size. In other experiments, hard clams (11 mm) were planted at densities of 380, 760, 1520 and 3040/m² in protected cages in South Carolina (Manzi *et al.*, 1980). Clams grew from 11 mm (according to methods) or 13.9 mm (according to Table 1) to 39 to 40 mm in shell length in 13 months. No differences in final size

TABLE 2. Growth in mm of hard clams planted at densities of 509, 1009, 2018, and 3027/m² and sampled monthly on an intertidal sandflat at Cabbage Island, Georgia.

	509 m-2		1009 m-2		2018 m-2		3027 m-2	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
June 1982	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
July 1982	8.5	8.4	8.7	8.8	8.9	9.0	8.2	8.9
August 1982	11.0	12.1	11.9	12.0	12.7	11.3	12.3	11.1
September 1982	13.3	11.9	13.2	14.0	12.0	13.0	12.4	13.0
October 1982	18.3	16.4	17.8	18.0	16.9	17.9	17.5	17.1
November 1982	23.3	21.3	22.6	23.7	21.5	22.1	21.5	21.5
December 1982	24.0	21.4	22.7	24.4	21.5	23.3	22.2	21.5
January 1983	25.2	22.7	24.6	25.7	22.3	25.0	23.5	22.3
April 1983	26.6	26.7	26.8	24.6	26.6	25.2	25.2	24.5
June 1983	35.0	35.2	34.5	34.7	32.9	32.3	31.0	----
September 1983	43.9	44.3	41.3	42.2	35.3	35.0	31.1	----
December 1983	49.7	49.0	44.3	45.0	35.6	37.2	33.0	----

TABLE 3. Average percent survival per clam density per month for hard clams planted in protective cages on an intertidal sandflat at Cabbage Island, Georgia.

Density	$509m^{-2}$	$1009m^{-2}$	$2018m^{-2}$	$3027m^{-2}$	Overall Survival
July 1982	89.3	66.2	83.3	59.5	76.5
August 1982	86.6	95.0	87.6	85.9	87.9
September 1982	83.0	97.3	94.8	95.5	94.6
October 1982	100.0	100.0	99.1	99.7	99.6
November 1982	99.1	99.5	100.0	99.2	99.5
December 1982	100.0	99.1	100.0	100.0	99.9
January 1983	98.2	97.7	99.1	99.7	99.1
April 1983	100.0	100.0	98.6	97.7	99.0
June 1983	100.0	100.0	99.1	100.0	99.6
September 1983	100.0	97.7	98.6	100.0	99.0
December 1983	100.0	100.0	98.6	97.9	98.8

between densities occurred; however, survival ranged from 9 to 19% and densities at the end of the experiment were approximately equal. In Georgia, clams (13 to 26 mm) were planted in cages and unprotected plots at densities of 108, 269, 538 and 807/m² (Godwin, 1968). No difference in final size (ANOVA $\propto = 0.05$) occurred, but mortality ranged from 0 to 60% in cages and 48 to 100% in unprotected plots. Eldridge *et al.* (1979) recommends seeding plots with 12 to 15 mm-size seed clams at 300/m². Menzel (1971a, b) recommends 250 to 538/m² as a suitable seeding density. In this experiment, seed clams at 509/m² reached an average size of 44 mm in 16 months as compared to 19 months for a larger size seed clam in South Carolina (Eldridge *et al.*, 1979). Clams at 1009/m² in this study were approaching 44 mm after 16 months and reached it after 19 months, indicating an optimum seeding density of 500 to 750/m² for Georgia.

In this experiment, 6-mm seed clams were tested as compared to > 11-mm size used by Manzi *et al.* (1980), Eldridge *et al.* (1979), and Godwin (1968). Clam survival in this study using 6-mm seed clams was higher than that for > 11-mm in the other experiments because cages were checked monthly to remove newly set crabs (Fig. 3). When the replacement seed clam cage was checked in October, 1982, there were no clams but one 75-mm blue crab. Cages seeded earlier at the same site with 10-mm clams and checked seasonally had 14 to 31% survival after a year (Walker, 1984) because blue crabs and/or mud crabs settled in the cages and were allowed to obtain a size capable of preying upon the clams. Thus, if the top cm of sediment is sieved to remove crabs at least monthly until clams reach approximately 18 mm, then high clam survival is possible and clam mariculture at high densities is feasible.

The difference in growth as a function of sampling time is important in terms of clam growth and survival. The difference in growth between clams sampled monthly and those sampled seasonally may be due to stress. Before planting, clams had been stressed due to handling and shipping procedures. Once planted, clams in Cage I were stressed monthly by being redug and handled; whereas, those in Cage II received this treatment only seasonally. Clams in these cages appear to be relatively free of predation from blue and mud crabs once they reach a shell length of 18 mm (Table 3). Clams sampled seasonally obtained this size a month earlier than those sampled monthly. Crabs which enter the cages in this experiment were removed monthly and were not allowed to reach sufficient size to

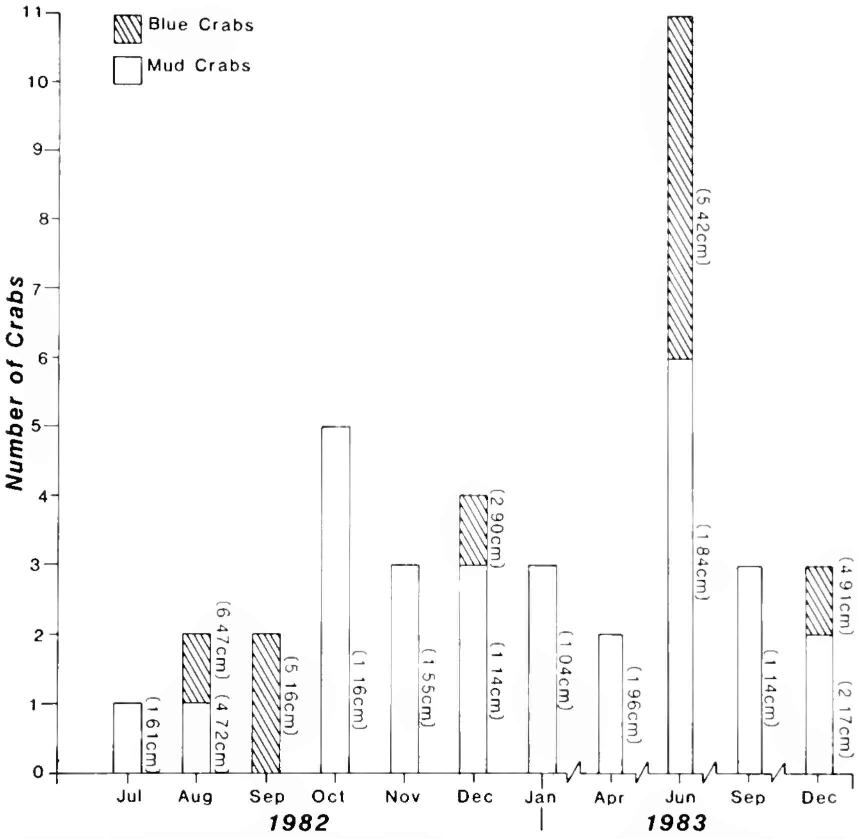

FIG. 3. Number and species of crabs removed from experimental clam cages located on an intertidal sandflat at Cabbage Island. The number in parenthesis is the average carapace width per crab species.

prey upon larger size clams (i.e., for *P. herbsti* 35 mm (Whetstone and Eversole, 1977) and for *C. sapidus* 40 mm (Arnold, 1983)). Since preventing crab entry is not possible, high clam survival is dependent upon removal of crabs and clams growing to a predation-free size.

Planting time may also prove to be an important factor in clam growth, and survival. In the southeastern United States clams grow year around with best growth occurring in fall and spring (Eldridge *et al.*, 1976, 1979; Menzel, 1963). *Mercenaria mercenaria* seed clams obtained from a Connecticut hatchery and grown in coastal Florida grew well in spring and fall with slow growth in winter and least growth in summer; however, with natural sets of *Mercenaria campechiensis* seed clams growth was best in spring and fall, rapid in summer and slowest in winter (Menzel, 1963). *Mercenaria mercenaria* seed clams from a North Carolina hatchery and planted in coastal South Carolina grew best in spring and fall, with least growth in winter (Eldridge *et al.*, 1979). In Georgia, *Mercenaria mercenaria* seed clams from a Virginia hatchery and those spawned from a natural Georgia stock grew best in spring and fall with good growth in summer and least growth in winter (Walker, 1984 and unpublished data). Thus, by planting in early spring in Georgia, clams may be allowed to pass through three seasons of good growth before reaching the winter growth period. Furthermore, by planting in early spring or late winter, clams may grow to a sufficient size to prevent their predation by newly metamorphosed crabs which enter the cages. Blue crab spawning occurs from early May through October in Chesapeake Bay (Van Engle, 1958), from March to September in Georgia (Palmer, 1974) and from February to October in Florida (Tagatz, 1968). Peak spawning for blue crabs occurs from June to October. Mud crabs spawn from late spring

through summer in South Carolina with highest numbers of newly metamorphosed crabs occurring in July and August (Dame and Vernburg, 1982) and from February to October in Florida with peak spawning in June to October (Tagatz, 1968). Thus, by planting seed clams in late winter or early spring, clams may grow to sufficient size to prevent predation by newly metamorphosed crabs in Georgia before the peak spawning season of crabs are reached.

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OCCURRENCE OF THE STRIPED RAM'S HORN SNAIL, *MARISA CORNUARIETIS*, IN CENTRAL TEXAS (AMPULLARIIDAE)

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Marisa cornuarietis (Linnaeus, 1758) is a large planorboid-shaped, prosobranch snail belonging to the apple snail family, Ampullariidae. Native to an area of tropical America from Panama to the Guianas and Trinidad (Baker, 1930; Pain, 1950), this species has subsequently become established in Puerto Rico, Cuba and Florida (Harry and Cumbie, 1956; Penalver, 1950; Hunt, 1958).

In June 1983, a population of *M. cornuarietis*

was discovered in the San Marcos River in a municipal park in San Marcos, Hays Co., Texas. A sample of ten adults and two juveniles was collected in a short period of time. Within the park, a portion of the banks of the river consist of concrete walls which support a noticeable growth of algae. Water temperature and chemistry are relatively constant, because the locality is only 550 to 850 river-meters below San Marcos Springs. Water temperature of San Marcos Springs varies from 21.7°C to 23.3°C. Dissolved chemical levels are fairly constant, e.g. clacium, 81 to 90 mg/1; magnesium, 15 to 21 mg/1; bicarbonate, 250 to 334 mg/1; pH, 6.6 to 7.8; dissolved solids, 310 to 349 mg/1 (Guyton & Associates, 1979).

The population sample included adult and juvenile snails with variation in number of bands as well as darkness of bands and background color. Most likely source of the population is a disgruntled aquarist who discovered that *M. cornuarietis* eats essentially all aquatic vegetation. Unwanted and released animals often become environmentally destructive. (Courtenay and Robins, 1973).

Degree of environmental impact of *M. cornuarietis* upon the aquatic communities of central and southern Texas in the future will be determined by degree of tolerance to low winter temperatures and poor summer water quality in habitats other than spring-fed streams. Pain (1950) reported a "preference for small clear woodland streams and pools." Robins (1971) reported that *M. cornuarietis* withdraw into shells and aggregate on the bottom at water temperatures of 19°C and below. Five hours exposure to 8°C is fatal, but this species can survive 24 hours at 11°C. On the upper end of the range of thermal range, *M. cornuarietis* feed normally at 35.5°C with the "upper limit" of the short-term heat tolerance being 39°C (Robins, 1971).

Substantial environmental impact is possible according to previous studies on *Marisa* (Robins, 1971). Environmental impact could be greatest upon the restricted Central Texas Spring Snail, *Elimia (Elimia) comalensis* (Pilsbry, 1890), which occurs in this portion of the San Marcos River. At the present time these two aquatic snails occur micro-sympatrically on the algae-covered concrete walls. However, at this point no data exist concerning population trends of either species. Also present on the banks of the San Marcos River is Texas wild rice, *Zizania texana* Hitchcock, a species currently listed as Endangered by the U.S. Fish and Wildlife Service. Likelihood of feeding by *M. cornuarietis* upon roots of *Z. texana* is unknown at this time.

Ongoing studies are concentrating on bionomics and potential expansion of *Marisa cornuarietis* in Texas waters.

I thank Brian D. Frisbie for bringing this population to my attention.

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AGATHODONTA NORTONI, NEW SPECIES: LIVING MEMBER OF A LOWER CRETACEOUS TROCHID GENUS

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ABSTRACT

Agathodonta nortoni, *new species, from archibenthal (300 meter) depths in the Philippines, represents a living record of a genus presumed extinct since the Lower Cretaceous. It is assigned to the tribe Chilodontini, subfamily Margaritinae, in agreement with an earlier placement of other living genera in this group.*

In a preliminary report on classification of the trochid subfamily Margaritinae (McLean, 1982), I assigned such Recent genera as *Euchelus* Philippi, 1847, *Danilia* Brusina, 1865, and *Turcica* A. Adams, 1854, to the tribe Chilodontini of the subfamily Margaritinae, a group previously regarded as limited to the Mesozoic, Middle Triassic through Upper Cretaceous. My allocation of these genera was based on a similarity of sculpture, aperture shape, and apertural dentition among the fossil and living genera.

Here I describe a new Recent species of the chilodontine genus *Agathodonta* Cossmann, 1918, which until now had been known only in the European Neocomian and Albian Stages of the Lower Cretaceous, 110 to 135 million years in age. This living link to such Mesozoic genera as *Pseudoclanculus* Cossmann, 1918, *Chilodontoidea* Huddleston, 1896, *Wilsoniconcha* Wenz, 1939, *Chilodonta* Etallon, 1862, and the Recent genera mentioned above is a further indication that the Recent genera are related to the fossil genera of the Chilodontini.

Shell characters of the chilodontine genera are: clathrate sculpture, some expression of apertural dentition, and an oblique aperture with the entire apertural rim in the same plane, enabling a close fit against the substrate. Living genera have epipodial and radular features in common, essentially as described by Beu and Climo (1974) for their new species *Danilia insperata*. Based on shell and radular characters, *Mirachelus* Woodring, 1928, is also a member of the group.

This and my earlier note (McLean, 1982), are preliminary to a full revision of higher classification in the Trochacea (in collaboration with C. S. Hickman), in which epipodial and radular characters of chilodontine genera will be illustrated.

Genus *Agathodonta* Cossmann, 1918

Agathodonta Cossmann, 1918: 200; Wenz, 1938: 296 [as "*Agnathodonta*"]; Cox, *in* Knight *et al.*, 1960: 249. Type species (original designation): *Trochus dentigerus* Orbigny, 1843. Lower Cretaceous (Neocomian).

Agathodonta dentigera (Orbigny, 1843)

Trochus dentigerus Orbigny, 1843: 185, pl. 77, figs. 9-12.
Agathodonta dentigera, Cossmann, 1918: 200, pl. 7, figs. 8-11; Wenz, 1938: 298, fig. 653; Cox, *in* Knight *et. al.* 1960: 249, fig. 160, 2.

"High turbiniform, anomphalous, with strongly convex whorls and base; ornament granose spiral cords; columellar lip with two strong, obtuse teeth." Cox, in Knight *et al.* (1960).

In addition to the type species, Cossmann (1918) referred two other species to *Agathodonta: Trochus guyotianus* and *T. tollotianus*, both of Pictet et Roux, 1849, from the Albian Stage of the Lower Cretaceous.

Agathodonta is characterized by two pronounced columellar plications, a trait shared with the Jurassic *Wilsoniconcha* Wenz, 1939, which differs in having a pupiform shape, and the Recent *Turcica*, which has a much larger shell with flat-sided whorls. *Turcica* was assigned by Keen, *in* Knight *et al.* (1960), to the Monodontinae, but is related to *Euchelus* and *Danilia* on the basis of radular, and epipodial characters.

The genus *Danilia*, recently reviewed by Beu & Climo (1974), differs from *Agathodonta* in having an exterior thickening of the final lip, and in

having a single columellar plication. According to these authors, *Danilia* has a fossil record dating from the Lower Cretaceous (Albian), nearly as old as *Agathodonta*. Six living species of *Danilia* were reported to occur offshore in archibenthal depths similar to those in which our new species of *Agathodonta* is found.

The only living trochacean genus with a longer fossil record than that of *Agathodonta* is *Angaria* Röding, 1798, which dates from the Upper Jurassic (Cox *in* Knight *et. al.*, 1960). Rather few living trochacean genera originated as early as in the Mesozoic. Aside from *Angaria*, *Agathodonta*, and *Danilia*, only 13 additional living trochacean genera were reported by Keen, *in* Knight *et al.* (1960), in the Mesozoic, all in the Upper Cretaceous.

Agathodonta nortoni, *new species*

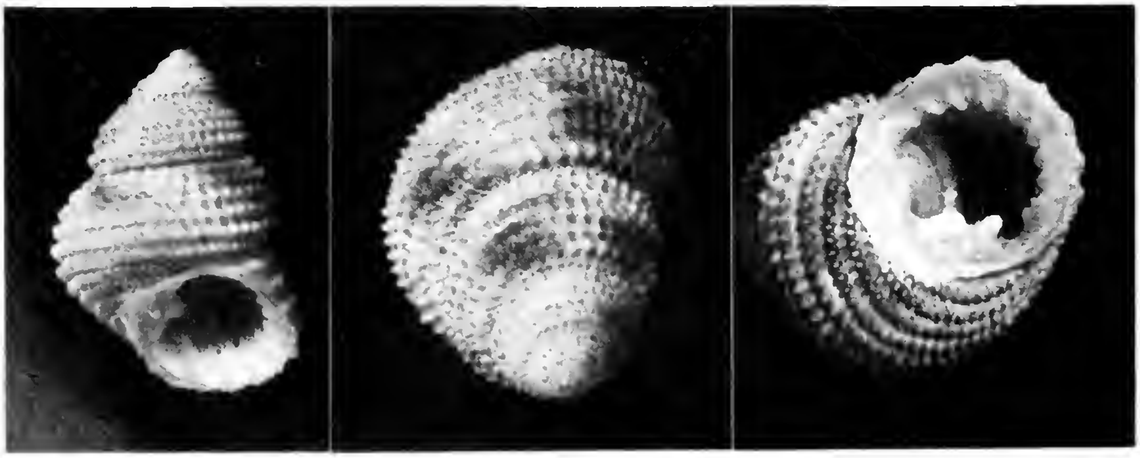
Figures 1-3

Description of holotype – Shell small; height 10.6 mm, maximum diameter 7.8 mm. Periostracum thin, in lamellar ridges; color uniformly buff with scattered, irregular brown markings. Protoconch eroded, teleoconch whorls 5½; whorls rounded, suture deeply impressed, slightly descending on last whorl; aperture markedly oblique; umbilicus absent. Spiral sculpture of strong cords and equal interspaces: 3 on 2nd whorl, 4 on third whorl, 6 on 4th and penultimate whorl, seventh cord emerging at aperture; base with 3 additional cords. Axial sculpture of oblique ribs weaker than spiral cords, producing strong projecting nodes at intersections. Aperture circular, nacreous within; columellar wall with two strong projecting folds, uppermost the larger, with notch and adjacent denticle below the two main plications; columellar shield forming a slightly raised peritreme, nearly concealing spiral sculpture over which it lies; columellar shield with 6 low tubercles. Lip thickened by apertural ridge within, with 9 lirae corresponding to interspaces of exterior spiral cords; apertural ridge with single, small pustules between lirae. Chitinous operculum present.

Type locality – 296-320 m on sand bottom, off Baltazar Island, Marinduque Province, Philippine islands (approximately 13°14'N; 121°49'E) (coordinates of island, U.S. Board on Geographic Names Gazeteer).

Holotype – Los Angeles County Museum of Natural History (LACM), cat no. 2031, collected by James E. Norton, 17 October 1966. The single specimen was collected alive; the operculum was in place but efforts to extract the operculum and body after soaking in trisodium phosphate solution were unsuccessful.

Discussion – *Agathodonta nortoni* is smaller than the Cretaceous *A. dentigera*, for which Orbigny gave a height of 18 mm. It further differs from *A. dentigera* in having the interior of



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FIGS. 1-3. *Agathodonta nortoni* new species, holotype; shell length 10.6 mm. **1**, Apertural view; the uppermost columellar plication does not show in this view; **2**, Oblique dorsal view; **3**, View perpendicular to the plane of the aperture, showing the two columellar plications, a notch and bordering node below the lowermost plication, the apertural ridge and strong lirae.

the outer lip thickened and prominently lirate, rather than thin and smooth.

Although I prefer not to base new species on single specimens, this species can be confused with no other. I therefore make an exception to call attention to the record of this genus in the Recent fauna.

The name commemorates the late James E. Norton, whose collecting in the Philippines during the 1960s has greatly enhanced the research potential of the LACM mollusk collection.

(Note Added In Proof)

In a recently published paper, Guidastri *et al.* (1984) transferred *Putzeysia* Sulliotti, 1889, from the Calliostomatinae to the Margaritinae, noting that the Mediterranean species *P. wiseri* (Calcara, 1842) has many features of such genera as *Danilia* Brusina, 1865, and *Mirachelus* Woodring, 1928, except for lacking the columellar tooth of these genera. *Putzeysia* is evidently another member of the tribe Chilodontini, one lacking apertural dentition, as does *Euchelus* Philippi, 1847.

Acknowledgments

I am particularly grateful to Tina Norton (Mrs. James E. Norton) for the gift of the Norton Collection to the LACM in 1981. I also thank Alan G. Beu, Eugene Coan, Myra Keen, and Patrick I. LaFollette for reading the manuscript and offering helpful suggestions.

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CRITIQUE ON STENZEL'S BOOK ON THE OSTRACEA

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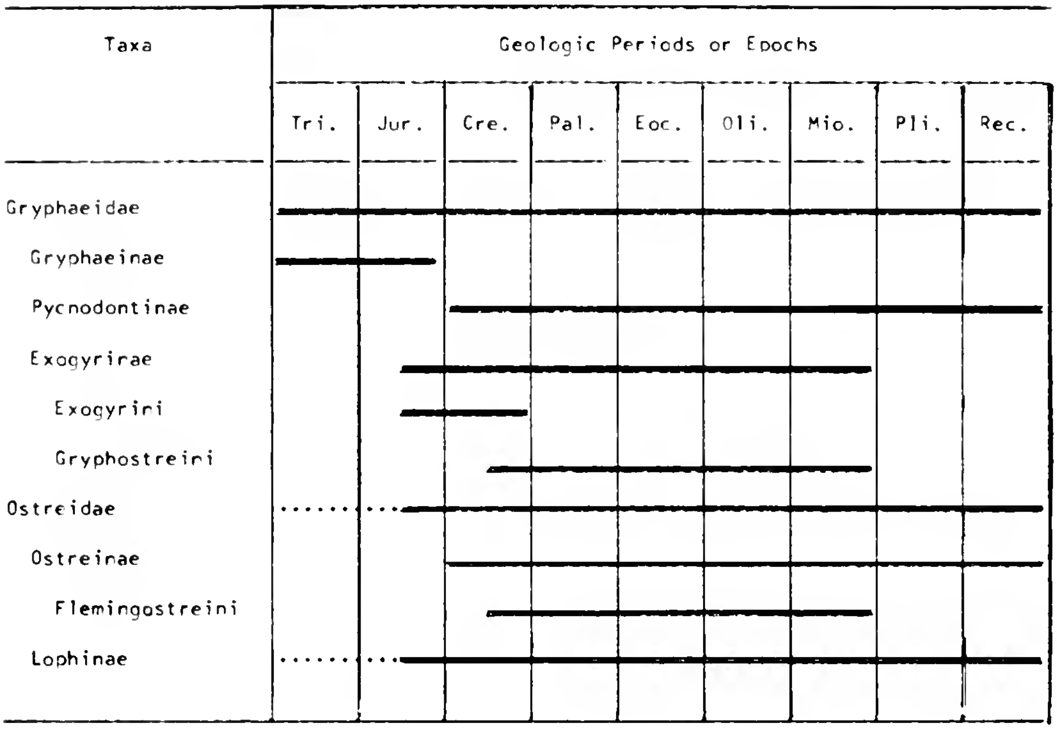
ABSTRACT

Stenzel assumed that the Ostracea are diphyletic and that the Gryphaeidae and the Ostreidae arose independently from two similar but different ancestral groups. Although the fossil record of the Ostracea is excellent, the stratigraphic evidence tends to refute Stenzel's assumption. It is more likely that the Gryphaeidae appeared first and that the Ostreidae arose later from a gryphaeid ancestor. The Ostracea are a distinctive group and appear to be monophyletic.

Stenzel (1971) subdivided the superfamily Ostracea into two families, five subfamilies, three tribes, and more than 50 genera and subgenera. This includes both fossil and living taxa, and the fossil record of the Ostracea is excellent because the shell is commonly thick and composed of resistant calcite. Furthermore, the Ostracea live in shallow seas where the fossil record is best. Stenzel did not analyze his extensive data of these groups stratigraphically. If one looks at the geologic ranges of the families, subfamilies, and tribes, one will see a significant fact (Fig. 1). All of the taxa above the generic level appeared no later than the middle Cretace-

FIG. 1. Geologic ranges of families, subfamilies, and tribes of the Ostracea. Dotted lines indicate doubtful distribution.



ous, about 100 million years ago and no more than 95 million years after the Ostracea appear in the fossil record. In other words, no new families, subfamilies, or tribes of the Ostracea have appeared in the last 100 million years. This pattern of evolution of a major taxon is a typical one in that the primary differentiation appears early in its history. The more primitive family (Gryphaeidae) appeared without doubt in the late Triassic Carnian Stage, but the Lophinae of the family Ostreidae doubtfully appeared as early as the Gryphaeidae and may not have arisen before the middle Jurassic.

In Table 1 the geologic ranges of the genera and subgenera of the Gryphaeidae and Ostreidae have been recorded. The Gryphaeidae are the more diverse from the Triassic through the Paleocene, with the greatest dominance of the Gryphaeidae over the Ostreidae in the Jurassic. It seems evident from the data that the Cretaceous was the time of greatest diversity of the Ostracea. All but one of the subfamilies lived during that period; and the warm, shallow, widespread seas were conducive to speciation during the Cretaceous. The Exogyrini became extinct at the end of the Cretaceous, and possibly 12 genera and subgenera failed to survive the Cretaceous Period. The Ostreidae and Gryphaeidae were equally affected by this major period of extinction. The Gryphaeidae are represented by few genera and subgenera after the Cretaceous, but the Ostreidae did increase in diversity during the Eocene. The tribes Grypho-

TABLE 1. Geologic range of genera and subgenera of the Gryphaeidae and Ostreidae. Genera and subgenera are considered of equal rank in this compilation.

Periods of Epochs	Gryphaeidae	Ostreidae	Total
Recent	2	6	8
Pliocene	2	6	8
Miocene	5	6	11
Oligocene	6	6	12
Eocene	5	10	15
Paleocene	5	3	8
Cretaceous	16	13	29
Jurassic	9	2	11
Triassic	2	1?	3?
Totals	52	53	105

streini and Flemingostreini became extinct at the end of the Miocene and four genera and subgenera disappeared at the Miocene-Pliocene boundary. Three of the four genera and subgenera that became extinct in the Miocene have been allocated to the Gryphaeidae. This accelerated extinction took place at the time that the seas became cooler and the onset of a major period of glaciation in the polar regions. As I pointed out (Nicol, 1978), even the Ostreidae, which can live in colder water than other shell-cemented pelecypods, do not live in areas where the sea water is less than 10° C during the warmest month of the year, and no shell-cemented pelecypods live in the polar regions nor the deep sea today. The Gryphaeidae have only two living genera and few living species, whereas the Ostreidae are represented by six genera and about 50 living species.

Stenzel (1971) came to the conclusion that the Ostracea are diphyletic. He thought that the oysters arose from two different but similar ancestral stocks. The Gryphaeidae first appeared in the northern circumpolar region, and the Lophinae of the Ostreidae arose in the Mesogean and Pacific realms. In other words, these two basic oyster stocks originated in two different marine provinces in the late Triassic. On the basis of shell morphology and comparative anatomy of the soft parts, the Gryphaeidae and Ostreidae have several consistently distinctive differences, as Stenzel noted, and the Gryphaeidae have the more primitive morphological characters. The appearance of the Gryphaeidae during the late Triassic is without question, but Stenzel claims that the Ostreidae appeared at approximately the same time. However, when one looks at Stenzel's basic data, there seems to be some doubt as to the first appearance of the genus *Lopha* of the Ostreidae. On page N1056 Stenzel has this to say: "Recognition of *Lopha* found in the Triassic deposits is difficult. Externally the lophas are quite similar to some species of *Enantiostreon, Atreta, Placunopsis,* and *Pseudomonotis.* The former are attached by their left and the latter by their right valves. The distinction cannot be made unless location of the adductor muscle insertion is clearly visible. However, most specimens found in Triassic deposits have tightly closed valves." The figures of Triassic *Lopha*, p. N1055, appear inconclusive because only three badly fragmented valves of the interior view are figured. Furthermore, Stenzel does not assign any of the Triassic lophas to his subgenera–*Lopha, s. s.* (Miocene to Recent), *Abruptolopha* (Cretaceous), or *Actinostreon* (Jurassic, Cretaceous). One wonders if *Lopha* is nothing but a form genus because the Paleocene, Eocene, and Oligocene, as well as the Triassic, are not mentioned in the geologic ranges of the subgenera of *Lopha*. The genus *Lopha* may not have appeared before the middle Jurassic. The fact that the Gryphaeidae are more diverse as to genera and subgenera in the Triassic, Jurassic, and Cretaceous also leads me to believe that the Gryphaeidae appeared some time before the Ostreidae.

Stenzel assumed that because the Gryphaeidae and the Ostreidae have several distinct basic differences and that these two families appeared at essentially the same time in two different marine provinces, they must have arisen from two different but similar stocks, and, thus, the Ostracea are diphyletic. He also assumed that the Gryphaeidae and Ostreidae arose slowly over a period of millions of years from their ancestral stocks, but there is no evidence of this slow evolution in the fossil record. However, the pattern of diversity as seen in the fossil record is very different from Stenzel's assumption on the evolution of the Ostracea. As I have pointed out (Nicol, 1972), the basic differentiation of the animal phyla occurred in the late Precambrian, Cambrian, and Ordovician, and this explains why, in part, there are more animal phyla living in the seas than in fresh water or on land. Even a large number of classes of animals can be traced back to the Ordovician or earlier in the fossil record. It seems to be a rule that the primary differences within the higher taxa (phyla, classes, orders, families) occur at the outset of the history of the group, and the evolution of the Ostracea fits into this general pattern.

I prefer to think that the Ostracea are monophyletic. It seems to me that it is every bit as logical to believe that such a distinctive group as the Ostracea arose once and within a relatively short time span (no more than one or two million years) from a single ancestral species, as to consider that this distinctive group arose from two different but similar ancestral species. The basic

data given by Stenzel are questionable in support of his thesis, despite the fact that the fossil record of the oysters is excellent. It appears that the Gryphaeidae are the sole ancestral stock of the Ostracea, and the Ostreidae arose from the Gryphaeidae no earlier than middle Jurassic time.

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BELLAXINAEA, A NEW SUBGENUS OF GLYCYMERIDIDS (PELECYPODA) FROM THE WESTERN HEMISPHERE

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ABSTRACT

The new pelecypod subgenus Bellaxinaea *is proposed for a distinctive group of split-ribbed glycymeridids which can be allocated to the genus* Tucetona. Bellaxinaea *is confined to the tropical western hemisphere, and its geologic range is from late Eocene to Recent.*

Woodring (1973, p. 521) recognized a distinctive stock of tropical American glycymeridids which he referred to as the group of *Glycymeris arctata*. Woodring noted that the species of this group generally increased in size from the Eocene to the late Miocene. He also discussed the relationships of several Oligocene and Miocene species.

As Nicol (1956) pointed out, most fossil and living species of glycymeridids can be separated into two major groups based on the type of radial ribs. The more ancient group is typified by *Glycymeris, sensu stricto.* This group has shown little change in the type of ribs since the inception of the Glycymerididae during the early Cretaceous. The radial ribs of this group are relatively flat with superimposed radial striae. Living specimens commonly have a luxuriant growth of hairlike periostracum. This group is found living in both tropical and temperate seas, but is not found where the yearly average temperature is less than 5° C. The second group is typified by the genus *Tucetona*, and the radial ribs are raised and are either simple or divided. Superimposed radial striae are never present, and there is little or no periostracum on living specimens. This group does not appear before the Eocene and is almost exclusively confined to tropical seas. Woodring's group of *Glycymeris arctata* is clearly related to *Tucetona* on the basis of the radial ribs.

Family Glycymerididae Newton, 1922
Genus ***Tucetona*** Iredale, 1931
Subgenus ***Bellaxinaea*** *new subgenus*

Type species—*Axinaea intercostata* Gabb, 1860

Description—Small to medium-sized glycymeridids; valve outline circular to subtrigonal, symmetrical; ratio of convexity to height of both valves commonly less than 0.55; beaks small, orthogyrate; ligament amphidetic, small; hinge plate strong, with high arch; teeth small and numerous, from 20 to 35 in number, central teeth under ligament present in mature specimens; radial ribs raised and numerous, on umbonal region or in immature specimens simple, later dividing one or more times and with secondary radial ribs sometimes forming in the interspaces between the primary ribs; crenulations on interior ventral margin medium-sized to large, about 15 to 20 in number, ends sometimes truncated and bifid, central portion of

crenulations may or may not be depressed.

Geologic range—Late Eocene to Recent.

Geographic range—Tropical western hemisphere; Florida, Georgia, Mississippi, California, Trinidad, Brasil, Venezuela, Colombia, Panama, Costa Rica, Mexico.

The earliest species of *Bellaxinaea* commonly have the greatest number of radial ribs, as, for example, *Axinaea intercostata*. In other words, these oldest species tend to have more splitting of the primary ribs and also more secondary radial ribs developed between the primary radial ribs. There are, however, some exceptions to this general rule. *Bellaxinaea* has its greatest diversity of species during the Oligocene and Miocene.

One species that probably does not belong to *Bellaxinaea* is *Axinaea bellasculpta* Conrad, 1860. The description is short and vague, and the species was never figured. The locality is simply stated as Mississippi. Unfortunately, Dall (1898, p. 607) synonymized *Axinaea bellasculpta* and *Axinaea intercostata* with *Pectunculus arctatus* Conrad, 1848. What probably led Dall to synonymize *Axinaea bellasculpta* with the other two species is Conrad's statement in his description of *Axinaea bellasculpta*, "radii in the middle of the disk trilineate." We borrowed the one specimen from the Academy of Natural Sciences of Philadelphia labeled *Axinaea bellasculpta* and *Glycymeris bellasculpta* (catalog no. 16399). Neither of the two labels in the box is in Conrad's handwriting, according to Ms. Elana Benamy, and it has not been ascertained that this specimen is Conrad's type. However, the ventral margin is densely crenulate, which fits Conrad's description. One label has "*Axinaea bellasculpta* Conr. =*hamula* Morton," and the label also has "Cretaceous and Mississippi" on it. The collector is stated as Spillman. The specimen appears to be a Cretaceous species, and the ribbing is much like that of *Glycymeris, sensu stricto*, although the outer surface of the shell is somewhat worn. One can, at present, regard *Axinaea bellasculpta* Conrad as a *species inquirenda*, but not synonymous with *A. arctata* Conrad.

Species allocated to *Bellaxinaea*—Some of these species are synonyms, as Keen (1971) and Woodring (1973) have noted, and with detailed study there are likely to be no more than ten valid species.

1. *intercostata* Gabb, 1860. This species occurs in the *Rotularia vernoni* zone (Nicol and Jones, 1982) which is approximately equivalent to Puri's (1957) *Asterocyclina-Spirulaea vernoni* faunizone. This is the uppermost zone of the Crystal River Formation (Eocene) in peninsular Florida, and three specimens from this zone are figured herein (Figs. 1-3). This species also occurs in the Red Bluff and Mint Spring Forma-

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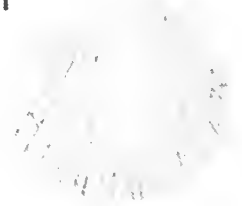

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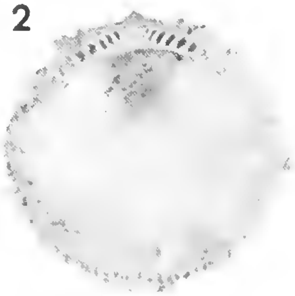

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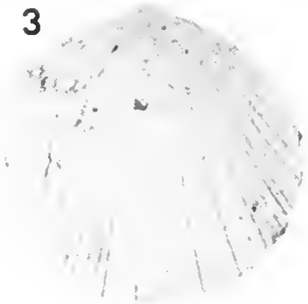

FIGS. 1-3. *Tucetona (Bellaxinaea) intercostata* (Gabb, 1860). **1.** Exterior view, left valve, height 15.8 mm, length 16.3 mm, hypotype cat. No. 5705. **2.** Interior view, right valve, height 16.6 mm, length 17.1 mm, hypotype cat. No. 5706. **3.** Exterior view, right valve, height 20.4 mm, length 21.0 mm, hypotype cat. No. 5707. The three specimens are siliceous pseudomorphs and are housed in the invertebrate paleontology collection at the Florida State Museum. Locality—Gainesville West Quadrangle in a shallow quarry 0.5 mi. south of the intersection of State Road 26 and I-75, west of Gainesville, Alachua County, Florida, SW¼, Sec. 4, T. 10S, R. 19E.

tions (lower Vicksburg Group) lower Oligocene in Mississippi. For a more detailed discussion of the stratigraphy of the upper part of the Crystal River Formation in peninsular Florida, see Nicol, *et al.*, 1976.

2. *arctata* Conrad, 1848. Mint Spring and Byram Formations in Mississippi and Rosefield Formation in Louisiana, lower Oligocene (middle and upper Vicksburg Group). See Dockery, 1982, for the differences between *arctata* and *intercostata*.

3. *bicolor* Reeve, 1843, Mexico to Ecuador (Pacific), Recent. A synonym of *multicostata* Sowerby, according to Keen, 1971.

4. *canalis* var. *colombiensis* Weisbord, 1929. Colombia, Miocene.

5. *canalis democraciana* F. & H. Hodson, 1927. Venezuela, Miocene.

6. *chemnitzii* Dall, 1909. Mexico to Ecuador (Pacific), Recent. A synonym of *multicostata* Sowerby, according to Keen, 1971.

7. *cookei* Dall, 1916. Flint River Formation, Georgia. Uppermost Eocene to lower Oligocene. Also see Dockery, 1982.

8. *crashleyi* Maury, 1925. Brasil, late Miocene.

9. *lamyi* Dall, 1915. Florida, late Oligocene or early Miocene.

10. *lamyi tampae* Mansfield, 1937. Florida, late Oligocene or early Miocene.

11. *lloydsmithi* Pilsbry and Brown, 1917. Colombia, Miocene.

12. *lloydsmithi striatidentata* Nicol, 1945 = *lloydsmithi multicostata* Weisbord, 1929, not *multicostata* Sowerby, 1833. Colombia, Miocene.

13. *minor* Orbigny, 1846. Mexico to Ecuador (Pacific), Recent. A synonym of *multicostata* Sowerby, according to Keen, 1971.

14. *multicostata* Sowerby, 1833. Mexico to Ecuador (Pacific), Recent.

15. *schencki* Nicol, 1947. Panama, Miocene.

16. *secticostata* Nicol, 1945. Costa Rica, Miocene.

17. *trilobicosta* Pilsbry and Brown, 1917. Colombia, Miocene.

18. *usiacurii* Anderson, 1929. Colombia, late Miocene.

19. *whaleyi* Nicol, 1947. California, late Oligocene or early Miocene.

Acknowledgments

We are indebted to Dr. George M. Davis and Ms. Elana Benamy for the loan of a cataloged specimen labeled *Axinaea bellasculpta* Conrad from the invertebrate paleontology collection at the Academy of Natural Sciences of Philadelphia.

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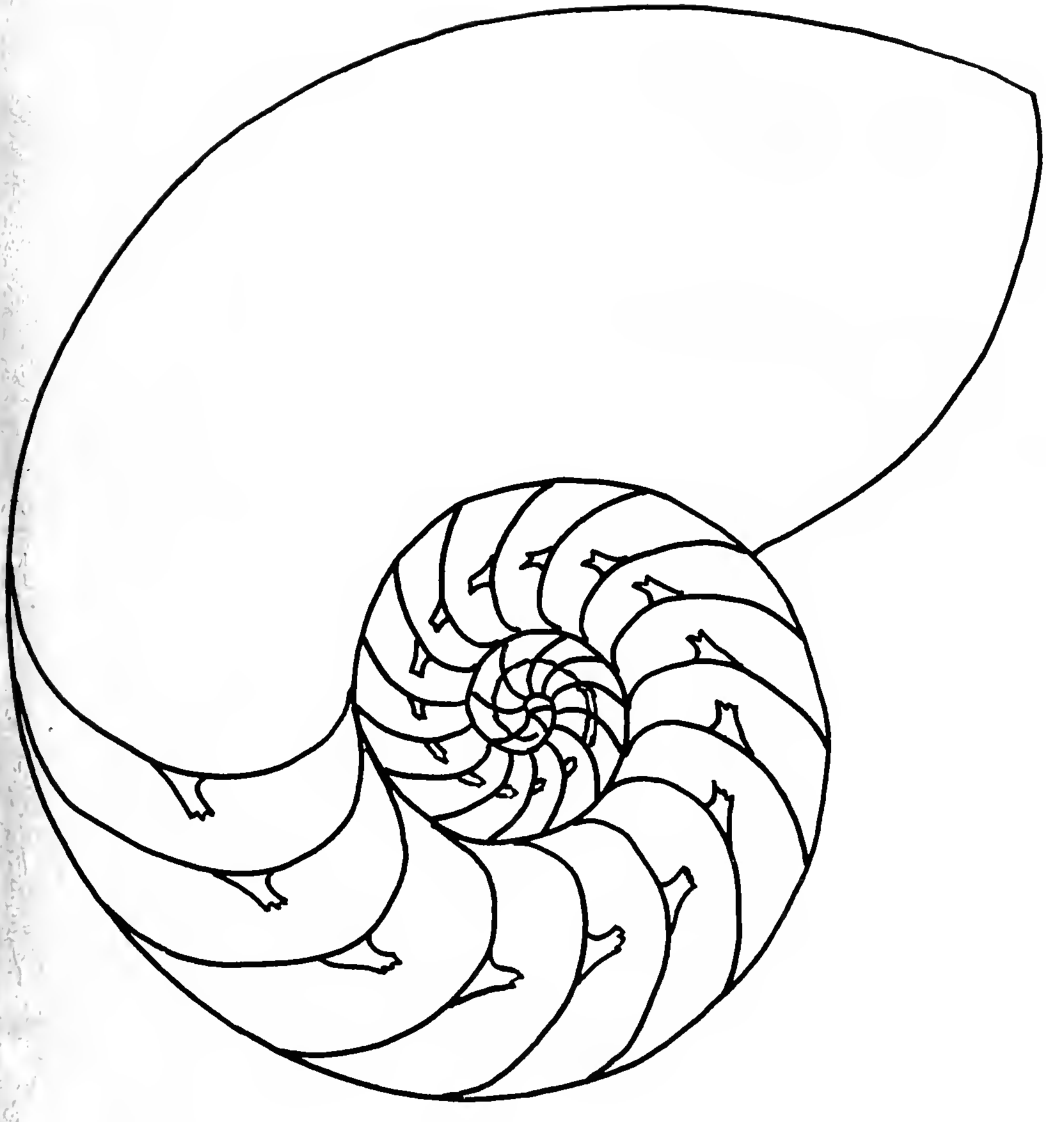

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CONTENTS

REARING JUVENILES OF THE FRESHWATER MUSSELS (UNIONIDAE) IN A LABORATORY SETTING

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ABSTRACT

This is the first report indicating success in rearing juvenile mussels in the laboratory. Juvenile mussels transformed by in vitro *methods (Isom and Hudson 1982) and those obtained from fish were reared successfully during the summer of 1984 and continuing.*

Basically, the mariculture procedures of Castagna and Kraeuter (1981) were modified for rearing the juveniles. Results of a matrix of experiments utilizing different water sources, plankton blooms, and sediments led to the successful rearing of juveniles.

Isom and Hudson (1982) first reported success in the transformation of glochidia of freshwater mussels (Unionidae) in vitro. Following this success, numerous attempts to rear the transformed juveniles in laboratory and field settings proved unsuccessful. Similar results have been reported from Europe, Australia (Young and Williams 1983; Walker 1981), and the United States (personal communication); that is, the juveniles obtained from fish live only a few days to two or three weeks, and then die.

Howard (1922) reported rearing of "*Lampsilis luteola*" in floating crates placed in a river setting, but no experiments were conducted, nor were food or environmental parameters revealed.

Late in the summer of 1983, we attempted to adapt the procedures of Castagna and Kraeuter (1981), used for growing the marine hard clam, *Mercenaria*, to growing freshwater juvenile Unionidae and were successful. The information reported in this paper largely resulted from our 1984 research which was catalyzed by personal assistance from Castagna and resulted in successful rearing of *Anodonta imbecilis* and *Dysnomia triquetra*.

Materials and Methods

Initiation of Culture

Mature glochidia from the species *Anodonta imbecilis*[1] were removed from culture medium, rinsed in distilled water, and placed into either large colorless Nalgene® containers (10 cm × 20 cm × 13 cm deep) filled with ca. 1,500 ml of lakewater or into beakers (250 ml) containing ca. 200 ml lakewater, both of which had plankton as food. *Dysnomia triquetra* were also placed in lakewater from the same source following encystment on a fish host. The 1,500 ml containers were seeded with 200-1,000 juveniles, while the 200 ml volumes had 50-250 juveniles. These containers were placed in two incubators having temperatures of 23°C and 30°C.

Maintenance of Cultures and Testing of Growth Variables

Water was changed daily, or twice daily, with Tennessee River water. Change was accomplished by pouring the contents of each container through a screen (Fig. 1) which had a mesh small enough to catch the juveniles. The

[1]See Clarke and Berg (1959) for comments on the correct spelling of *A. imbecilis* (Say 1829).

FIG. 1. Catching juveniles in 202 μm screen while changing water in growth containers.

mesh opening was usually 34 μm (Nitex®) for small juveniles. Later, as they grew, progressively larger-sized screens were used (75, 100, and 202 μm).

Prior to changing the water in the juvenile containers, the river water had been allowed to produce an algal bloom for one to four days. This was accomplished by pouring fresh river water through a 5 μm polypropylene sack filter (to allow smaller sized plankton to pass) into large 20 gallon (ca. 76 L) colorless Nalgene containers (Fig. 2). This water, containing a diversity of small plankton genera (Table 1) was held outdoors (it should be held in a greenhouse for winter blooms) in a semi-shaded area. Full sunlight kept the water at 3 or 4° C higher than the normal high temperature of 30°C reached in semi-shade and produced a lower algal bloom density having more ciliates. Algal blooms of 100,000-700,000 cells/ml were maintained. When plankton yields were low (cloudy days), plankton supplements were added from concentrated plankton prepared with a continuous flow centrifuge. This concentrate often included the diatoms and other algae scraped from the walls of the holding container.

Growth comparisons were also made using tri-algal cultures having three genera of green algae (*Selenastrum*, *Tetraëdon*, and *Chlorella*). Some tri-algal food was supplemented with Jim Dandy® catfish chow (32 percent protein). Also, addition of silt, fertilization, and frequency of change of cultured water were compared with growth rates and survivability of the juveniles.

Silt was collected and added to some groups of culture water by passing pond or lake substrate

FIG. 2. Filtering water with 5 μm sack filter to make small plankton culture.

TABLE 1. Representative Plankton Found in Cultured River Water.

Gonium	*Vorticella*
Anabaena (and/or *Anabaenopsis*)	*Scenedesmus*
Achnanthes	*Trachelomonas*
Navicula	*Crucigenia*
Oscillatoria (and/or *Lyngbya*)	*Phacus*
Bodo	*Stephanodiscus* (and/or *Cyclotella*)
Fragilaria	Chlorococcales
Eudorina	
Stentor	

through a 25 μm polypropylene sack filter. Addition of silt involved three comparisons: (1) river water with no additional silt (contained ca. 125 mg natural silt/L); (2) addition of silt suspension sufficient to cloud the water (contained at least 700 mg silt/L); and (3) addition of silt sufficient to produce a layer (ca. 1 cm) on the container floor.

Fertilization of some algal cultures was accomplished by the addition of 2 g of 13-13-13 (N-P-K) fertilizer to five gallons (ca. 19 L) of

river water. This is slightly less than the amount used to fertilize farm ponds.

Three water change frequencies were compared in the experiment: once daily, twice daily, and continuous flow. Continuous flow designs included flowing water into the top of a container which held the mussels, with side screens to allow water to escape; flowing water over rock substrate in a series of descending steps (Fig. 3); and flowing water up through a screen that the mussels were resting upon (Fig. 4). The last design would only work if the mussel holder was placed into an aquarium that was higher than the overflow of the holder. This overflow tube would drain water from a lower level than the aquarium top and, therefore, force water to pass up through the screen from under the holder. Flow rates for all of these containers were from a slow drip to 1.5 L/min.

Results and Discussion

Juvenile mussels of *Anodonta imbecilis* are the oldest that we have transformed and raised, as of this writing, in our laboratory. These juveniles measured over 5.1 mm in length after 74 days in river water. The original length of juveniles when they were introduced into lake-water was 0.28 mm (n = 20, $S_{\bar{x}}$ = 0.002). This represents over 18× increase in length and an increase in estimated side surface of over 110×. The juveniles have also increased in internal complexity. Their gills, initially three pairs of lobes, now are comprised of at least 23 finger-like lobe pairs. Siphons and a well-developed pelecypod foot are evident. The massive digestive organ, initially not visible, has spread throughout the visceral cavity and upper foot. The adductor muscles are large and easily seen, as is the dark intestine (Fig. 5).

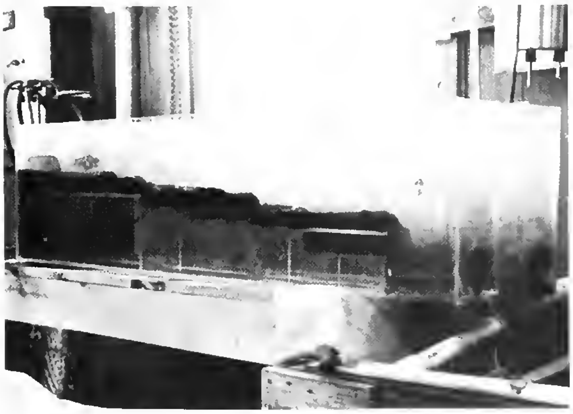

FIG. 3. Descending-step holder for juvenile mussels.

FIG. 4. Mussell holder designed for water ascending up through screen on which mussels rest.

A. imbecilis has proven to be a good laboratory animal, especially since it requires fish host for transformation, and glochidia are available most of the year (Hudson et al. 1984, in manuscript).

Plankton Feeding

Feeding by changing the water daily with trialgal culture water in 1983, even with addition of catfish chow suspension, would allow the juveniles to live and add on some shell growth for two to three weeks. During the second week, slowing of mussel activity and mortality was observed. This loss would continue until all juveniles were dead, usually about the third week. Castagna (personal consultation) indicated that this gradual slowing of acitivity and death over a period of a couple of weeks was indicative of starvation.

FIG. 5. *Anodonta imbecilis* 57-day-old, 3 mm juvenile showing internal development.

The use of naturally occuring plankton cultured for one to five days in fresh river water resulted in sustained life and growth of juveniles for the duration of the experiment in 1984; however, mortality often exceeded 90 percent within five to six weeks when silt was not added.

Effect of Silt

The above-mentioned mortality in juveniles was shown to be substantially decreased in cultures where silt was added. One experiment with *A. imbecilis*, involving over 500 juveniles in each of two containers, had only 10.2 percent survival at an age of 30 days in the container with no silt, while 89.1 percent survived in the container with silt additions. Another comparison involving 16 beakers containing ca. 50-250 juveniles each, eight receiving additional silt and eight without additional silt, resulted in significantly different survivability percentages with those in silt having 91.9 percent survival ($S_{\bar{x}}$ = 2.1) and those without silt having 68.9 percent survival ($S_{\bar{x}}$ = 9.2). The no-silt replicates in beakers may have had higher survival rates than the larger containers because the latter were replaced daily, whereas the juveniles in each beaker were screened and rinsed, but returned to the same beaker. This allowed natural silt to accumulate to some degree in the bottom of the beaker, even in beakers not receiving additional silt.

Mussel growth was also enhanced by silt additions. Although there appears to be considerable individual variation in growth rates, comparisons of 30-day-old randomly measured juvenile *A. imbecilis* revealed that those having additional silt had significantly greater growth than those without (Table 2). Another comparison involving the same treatments and species for 28-day-old juveniles showed similar results (Table 3).

Addition of greater amounts of silt, producing a layer (ca. 1 cm) which covered *A. imbecilis* juveniles in three beakers, yielded no significant increase in growth over the cloudy silt suspensions. The extremely heavy silt layer was not detrimental to survival or growth.

The fact that *A. imbecilis* survives and grows better with silt additives may be related to its ability to live naturally in pond and silty lake habitats. For comparison, approximately 100 *Dysnomia triquetra* juveniles, a typical "headwater" species, were obtained following transformation on fish and placed into one of two containers. Both containers were treated the same with the exception that silt suspension was added to one of them. After 18 days in the two treatments, the juveniles in the extra silt were significantly larger than those without additional silt and also had 85 percent survival, as opposed to 77 percent without extra silt (Table 4). This would imply that the need for silt is common to both lotic- and lentic-water species.

The mechanism of silt enhancement on the survival and growth of juveniles has not been clearly determined. It is possible that the silt

TABLE 2. Size (mm) of 30-day-old juveniles, *A. imbecilis*, with and without silt suspension.

Comparison Unit	*Juveniles with Silt*		*Juveniles without Silt*	
	Length	*Height*	*Length*	*Height*
n	23	23	23	23
range	.39-.82	.26-.65	.47-.65	.34-.56
$\bar{x}$	.64	.50	.57	.43
$S_{\bar{x}}$	.03	.01	.01	.0004

TABLE 3. Size (mm) of 28-day-old juveniles, *A. imbecilis*, with and without silt suspension.

Comparison Unit	*Juveniles with Silt*		*Juveniles without Silt*	
	Length	*Height*	*Length*	*Height*
n	20	20	20	20
range	.43-.73	.34-.56	.26-.52	.34-.52
$\bar{x}$	.61	.48	.45	.38
$S_{\bar{x}}$	.02	.01	.02	.01

TABLE 4. Size (mm) of *Dysnomia triquetra* juveniles held in culture for 18 days, with and without silt.

Comparison Unit	*Juveniles with Silt*		*Juveniles without Silt*	
	Length	*Height*	*Length*	*Height*
n	11	11	12	12
range	.47-.86	.39-.52	.39-.49	.34-.43
$\bar{x}$	.61	.46	.45	.38
$S_{\bar{x}}$	.03	.02	.01	.01

merely adds another food source in the form of associated organic particulate matter. Urban and Langdon (1984) reviewed the work of others and also treated the effect of artificial silt (kaolinite) on oysters (*Crassostrea virginica*) growth. In all cases a significant increase in growth was obtained when kaolinite was added. This phenomenon was attributed to one or more of three possibilities: (1) increased filtration rates; (2) adsorption of soluble organic food material onto the kaolinite, which was later easier to assimilate by the oysters; and (3) use of kaolinite to grind food in the alimentary canal, which should result in better absorption efficiency within the oyster.

The Effect of Temperature

Temperatures of 23°C and 30°C were compared in *Anodonta imbecilis;* however, comparisons of two samples of 23 individuals each, one at each of the above temperatures, indicated no significant difference in the growth of the mussels at an age of 30 days. No silt was added to either treatment. Another comparison involving the same temperatures, but with silt added to both temperature treatments, revealed a barely significant growth increase in the 30°C group (Table 5). This increase, compared to the above lack of difference without silt additions, may be the result of silt providing the additional needed energy for growth in the higher temperatures.

TABLE 5. Size (mm) of *Anodonta imbecilis* juveniles held in culture for 15 days at 23°C and 30°C, both with additional silt.

Comparison Unit	*23°C*		*30°C*	
	Length	*Height*	*Length*	*Height*
n	20	20	20	20
range	.34-.62	.26-.47	.39-1.1	.30-.82
$\bar{x}$	.49	.36	.58	.43
$S_{\bar{x}}$	.02	.01	.04	.03

Water Changing Variables

Frequency of water change was compared, with three containers changed twice daily as opposed to the standard practice where water was changed once daily. Growth rates and survivability were not significantly different in young 16-day-old juveniles. It seems reasonable, as the juveniles increase in size, food may become limiting; therefore, more frequent water changes would allow better growth.

The various flowing systems all failed to maintain living juveniles for more than a couple of weeks, with the exception of the one where the water was forced up through the screen which held the juveniles (Fig. 4). Most of our specimens were washed out during early back flushing of the screen and only two living and one dead juveniles remained. The two living ones were 0.43 and 0.47 mm long at 14 days old, which falls within the expected range. The success of this design is thought to be due to the fact that a large volume of water (usually > 1 L/min) passes directly past the juveniles. This large flow, coming in contact with the mussels, apparently provides enough total plankton for growth. The other designs, which usually had a lower flow of water coming into a more stagnant or harder to reach area, apparently did not provide the food volume necessary to sustain the juveniles.

While we have had no problems with disease, bleach treatments were tried in an effort to control bacteria and other organisms which may be attached to the juvenile shells. Treatment at recommended levels for marine bivalves (Castagna and Kraeuter 1981), 0.5 ml bleach/ 1,000 ml water in three beakers containing 10 juveniles each for one hour, resulted in survival of only 14 to 57 percent. Six other beakers, having the same age juveniles not treated with bleach, had 90 to 100 percent survival. Growth of the bleached individuals was not significantly different from non-bleached individuals. It appears that the juveniles are quite capable of coexistance with these extraneous organisms, and that bleach treatments are generally unnecessary and harmful.

Other Species

Most of the above work has resulted from data collected using *A. imbecilis*. Attempts were

made to rear other species, *Lampsilis ovata*, *Fusconaia ebena*, *Ligumia recta*, *Pleurobema cordatum*, and *Caruneulina moesta* (Figs. 6 and 7), in 1983, but their juveniles lived only a couple of weeks. In 1984 *Dysnomia triquetra* (Fig. 8), as already mentioned, are still thriving after 42 days in juvenile culture and show good growth and survivability (see section on silt).

Growth Rate

Overall growth of *A. imbecilis* was measured for the largest individuals in our oldest experi-

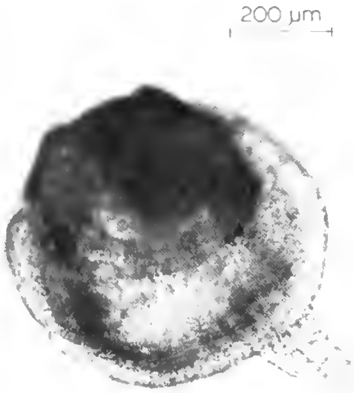

FIG. 6. *Lampsilis ovata* 10-day-old juvenile (shell length: .66 mm).

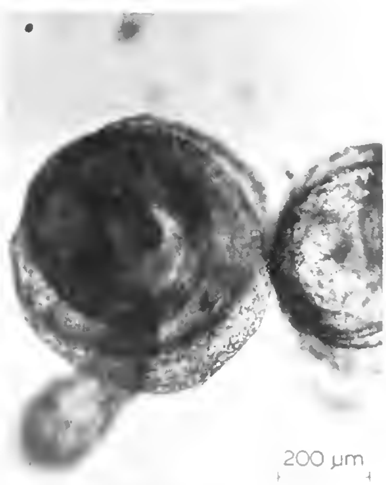

FIG. 7. *Carunculina moesta* six day-old-juvenile (shell length: .54 mm).

FIG. 8. *Dysnomia triquetra* 19-day-old juvenile (shell Length: 68.25 µm).

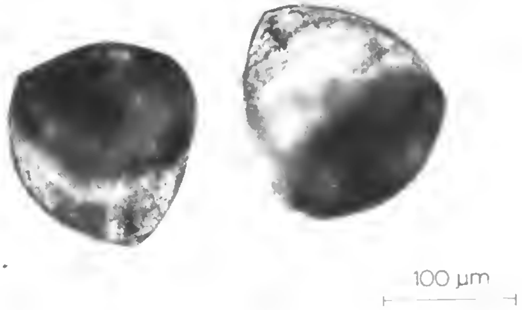

FIG. 9. Growth of largest individual *Anodonta imbecilis*.

ments. As seen in Fig. 9, the growth appeared fairly slow initially (0.16 mm/week during the first two weeks) and picked up substantially to 0.95 mm/week during the eighth week. The increase in size and complexity is easily seen when comparing a 1 day old juvenile (Fig. 10) with a 57 day old juvenile (Fig. 5). This tremendous increase in growth places a heavy demand by juveniles on the plankton food source, and is probably related to the death of juveniles during their third week in the 1983 culture attempts. We think these experiments demonstrate that this problem has been solved. Many cultures (between 2-4 mm) are now ready for field transplantation.

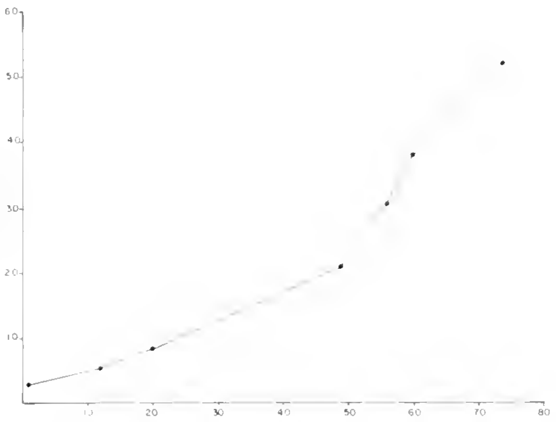

FIG. 10. *Anodonta imbecilis* one-day-old juvenile.

Application and Future Needs

Many more variables and species need investigation. This first breakthrough in the laboratory raising of juvenile freshwater mussels represents a significant step toward mussel conservation. Endangered species can now have their glochidia removed and transformed in the laboratory without injury to the parent mussel (Isom and Hudson 1982) and the juveniles can be grown to a size that will enhance their ability to survive when released into their natural habitat. This development may also have significance in future projects for the artificial farming of pearly mussels from which beads are made for cultured marine pearls.

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GASTROPODS COLLECTED FROM EASTERN OKLAHOMA BY DWIGHT ISELY IN 1911

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ABSTRACT

A collection of aquatic and terrestrial gastropods made by Dwight Isely in eastern Oklahoma in 1911 is reported. The collection comprises 32 lots, involving 18 species and 8 localities. Habitats at some localities have been greatly altered in the past 74 years.

Shepard (1982) reported the rediscovery of specimens of unionacean mussels collected by Frederick B. Isely during his survey of the mussel fauna of eastern Oklahoma in the years 1910 to 1912. F. B. Isely noted (1924:45) that during the field season of 1911 he was assisted

by "Dwight Isely of Fairmount College." Dwight and Frederick were brothers. Fairmount College was a progenitor of the present Wichita State University, Wichita, Kansas. Several members of the Isely family were involved with Fairmount College early in this century. Distler discovered some lots of gastropods collected by Dwight Isely in collections long stored at Wichita State University. These have subsequently been incorporated (Nos. 6157-6193) into the invertebrate collections of the University of Texas at El Paso.

The specimens were contained in small envelopes with locality of collection indicated on the outside and, in some cases, repeated on a slip of paper within the envelope along with an indication of Dwight Isely as the collector. Both aquatic and terrestrial snails were included. Comparison of the localities indicated on the labels shows them to correspond to localities reported by F. B. Isely (1924) in his survey of mussels. It seems, then, that Dwight Isely was collecting gastropods at these localities while involved in the survey of mussels in the summer of 1911. Eight localities are represented in his collection. These are listed below indicating (1) the corresponding station number of F. B. Isely (1924), (2) date of collection (all in 1911), (3) county in which collection was made, (4) locality data supplied on the lots of gastropods, and (5) additional remarks.

27. August 26. Noble Co. "Black Bear Creek, Black Bear." Black Bear is on the St. Louis-San Francisco Railroad in the center of Sec. 32, T. 22 N, R. 1 E, ca. 0.65 km S of Black Bear Creek.

28. July 20. Tulsa Co. "Slough, Tulsa." F. B. Isely (1924:63) describes this locality as "A small nameless slough that entered the Arkansas from the south above Tulsa . . . ." "Arkansas" refers to the Arkansas River.

30. July 27. Cherokee Co. "Fourteenmile Creek, McBride." Fourteenmile (or Spring) Creek enters Grand River from the east. At present, the lower part of the creek is impounded and forms a major arm in the southeastern part of Fort Gibson Reservoir. F. B. Isely (1924:64) noted that his party ascended the creek some 2¼ miles (3.6 km) from its confluence with Grand River. This would place them in the area now covered by the reservoir, probably near NE¼, Sec. 1, T. 16 N, R. 19 E.

34. August 8. Mayes Co. "Pryor Creek, Pryor." F. B. Isely's locality was west of Pryor, probably near the intersection of Secs. 11, 12, 13, and 14, T. 21 N, R. 18 E.

36. August 9. Craig Co. "Big Cabin Creek, Vinita." Big Cabin Creek heads in northern Craig Co. and flows south. F. B. Isely collected on it at a locality west of Vinita, probably in Sec. 17, 20, or 21, T. 25 N, R. 20 E.

37. August 11. Cherokee Co. "Illinois R., Tahlequah." The Illinois River flows past the east side of Tahlequah.

38. Aquatic and terrestrial species collected on August 2 and 4, respectively. Wagoner Co. Aquatic species: "Marsh near Verdigris River, Wagoner;" terrestrial species: "Near Verdigris River, Wagoner." F. B. Isely's station was west of Wagoner on the Verdigris River at "Mingo Ferry." This area has been greatly modified in recent decades by channelization of the Verdigris River and with abandonment of much of the previous channel.

41. August 21. Rogers Co., Catoosa area. Two labels by Dwight Isely read: (1) "Near Verdigris River, Catoosa" and (2) "Near Spunky Creek, Catoosa." All specimens are land snails. F. B. Isely (1924:71, 72) noted that collections were made on the Verdigris River, below a ford, east of Catoosa and in lowermost Bird Creek, north of Catoosa. Spunky Creek flows past Catoosa, on the east, northeastward to its confluence with the Verdigris River and near the confluence, also, of Bird Creek with the Verdigris. At the present time this general area has been much modified by channelization of the Verdigris River, the installation of facilities at the Port of Catoosa, encroaching urbanization, freeways, etc.

In Table 1 identifications and numbers of shells of gastropods in the Dwight Isely collection are given, utilizing numbers of the collection stations of F. B. Isely discussed above. All lots contain at least some shells that appear to have been living or recently defunct at time of collection except for bleached shells (only) of *Polygyra leporina* and *Triodopsis divesta* from Locality 41.

The Dwight Isely collection contains several new county records for Oklahoma and documents presence of some species in areas that subsequently have been variously modified in

TABLE 1. Freshwater and terrestrial gastropods collected by Dwight Isely in Oklahoma in 1911. Number of specimens for each species is indicated for corresponding locality numbers of F. B. Isely (1924).

Species	Locality Numbers of F.B. Isely							
	27	28	30	34	36	37	38	41
Campeloma decisum (Say)			6			9		
Cincinnatia cincinnatiensis (Anthony)				9				
Elimia potosiensis (Lea)						25		
Physella gyrina (Say)	4		7	1	1	38	1	
Helisoma anceps (Menke)				1				
Planorbella trivolvis (Say)	2	1	3		2	7	1	
Pupoides albilabris (Adams)							2	
Gastrocopta armifera (Say)							8	
Succineid, sp. indet.	1							
Anguispira alternata (Say)								3
Glyphyalinia indentata (Say)							1	
Polygyra leporina (Gould)							1	1
Polygyra dorfeuilliana Lea								3
Stenotrema leai aliciae (Pilsbry)							2	2
Mesodon clausus (Say)			1		1			
Mesodon thyroidus (Say)							1	
Mesodon inflectus (Say)								9
Triodopsis divesta (Gould)								2

regard to habitats. This is especially true of Localities 30, 38, and 41, with Locality 30 now being within a large reservoir instead of along a small creek.

We are grateful to Mr. K. B. Isely, Wichita, Kansas, for information concerning the Isely family. Dwight Isely later became an entomologist, associated with the University of Arkansas and the state agricultural experiment station in Arkansas.

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CHAETOGASTER LIMNAEI (OLIGOCHAETA: NAIDIDAE) IN THE AQUATIC SNAIL, *HELISOMA TRIVOLVIS*, FROM CHARLES FORK LAKE, WEST VIRGINIA

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ABSTRACT

The oligochaete worm, Chaetogaster limnaei, *was recovered from 342 of 366 freshwater planorbid snails,* Helisoma trivolvis, *examined from February thru May 1981, and February thru November 1983. Monthly prevalence rates generally exceeded 80%, while mean intensity levels were ≤ 18* C. limnaei *individuals. Infections were somewhat higher in smaller snails for every month sampled, although differences were statistically significant (P<.05) only for March and April '81, and July '83. Temperatures of ≥ 26° C or ≤ 15° C supressed mean intensity levels of* C. limnaei.

Despite the occurrence of large numbers of freshwater oligochaetes in many parts of the United States, few detailed studies at the generic or specific level have been published on this group, comprised mainly of free-living species (cf. Maciorowski *et al.*, 1977). Thus it is not surprising that symbiotic oligochaete species have received little attention.

The objectives of this paper are to: determine monthly prevalence and mean intensity of *C. limnaei* infections in a restricted population of Planorbidae snails, *Helisoma trivolvis* (Say); determine if any correlation exists between host size and intensity of infection; and evaluate the effect of temperature upon a specific *C. limnaei* population.

Materials and Methods

A total of 366 *Helisoma trivolvis* individuals, 75 snails in 1981 (February thru May) and 291 in 1983 (February thru November), were collected from Charles Fork Lake, West Virginia (MG 70169125, USGS Topographic Map, Spencer Quadrangle, Photorevised 1976) and examined for *Chaetogaster limnaei*.

Snails collected each month in 1981 were placed in a common container with ≅ 4.0 liters of lake water, then carried to the lab. However, throughout 1983 each snail was placed in a separate vial with ≅ 100 ml of lake water (to preclude migration of naidids from one snail to another), then transported to the lab. Snails were kept segregated in a Freas Model 816 low temperature incubator at temperatures approximating the water temperature on date of collection. Within six to 36 hours of capture, all snails were measured for shell diameter with vernier calipers to the nearest 0.1 mm, dissected, then examined for *C. limnaei* individuals with the aid of a stereomicroscope. *Chaetogaster limnaei* individuals were examined while alive in water mounts, and identified by using the key of Hiltunen and Klemm (1980). Additional specimens were killed by freezing, fixed in 10% buffered formalin, stained with diluted Semichon's acid carmine (in 70% ethanol), dehydrated in an ethanol series, and cleared in methyl salicylate before mounting in Kleermount®. Voucher specimens were deposited in the USNM under Collection Numbers 081913, 081914, and 081915.

The ecological terms of prevalence and mean intensity follow the definitions of Margolis *et al.* (1982).

Results

Chaetogaster limnaei was recovered from 342 of 366 (93.4%) *Helisoma trivolvis* individuals examined. Monthly prevalence rates were high, falling below 80% only once. Monthly mean intensities were highest at temperatures of 16° C

to 26° C with ranges of worms deviating considerably from the mean (Fig. 1).

There was a low negative correlation between host shell diameter and number of *C. limnaei* individuals present for each month sampled, although significant (P<.05) levels of correlation were noted only for the months of March and April '81, and July '83 (Fig. 2).

Discussion

The present study demonstrated that temperature played an important role in the biology of a *C. limnaei* population. Notable increases in mean intensity levels were evident from April to May in both '81 and '83 when temperatures were rising from 14° C to 17° C; and again in October and November '83 when temperatures were falling through the 18° C to 14° C range (Fig. 1). Gruffydd (1965) also demonstrated that the most dramatic increase in mean intensity levels of *C. limnaei limnaei* in *Lymnaea pereger* occurred from April (mean ≅ 15) to May (mean ≅ 40) when temperatures were increasing from 10° C to 17° C. And Streit (1974) recorded a sharp increase in the mean number of *C. limnaei* during the Spring when temperatures were rising from ≅ 6° C to 13° C, reaching a maximum of 7.0 worms per host in May.

One would expect low temperatures to depress mean intensity levels, but until now there was no evidence that high temperatures (⩾ 26° C) could supress mean intensity levels as well (Fig. 1). This is understandable, because previous investigators rarely collected snails at ⩾ 26° C. Still, the role of temperature must be examined cautiously because another important variable – host size – may influence both prevalence and numbers of *C. limnaei* individuals in gastropods. For example, Buse (1971) noted a positive correlation between size of snail (*Lymnaea stagnalis*) and number of *C. limnaei vaghini* individuals. And Streit (1974), working with *C. limnaei* in the river limpet, *Ancylus fluviatilus*, reported correlations of r = 0.934 for host length versus prevalence, and r = 0.880 for host length versus number of *Chaetogaster*.

In a more extensive study Gruffydd (1965) stated that, ". . . in general, larger snails harbor more *Chaetogaster* than smaller snails." While that may have been true for his overall sample, the size frequency distribution of *L. pereger* samples for April and May were virtually identi-

Fig. 1

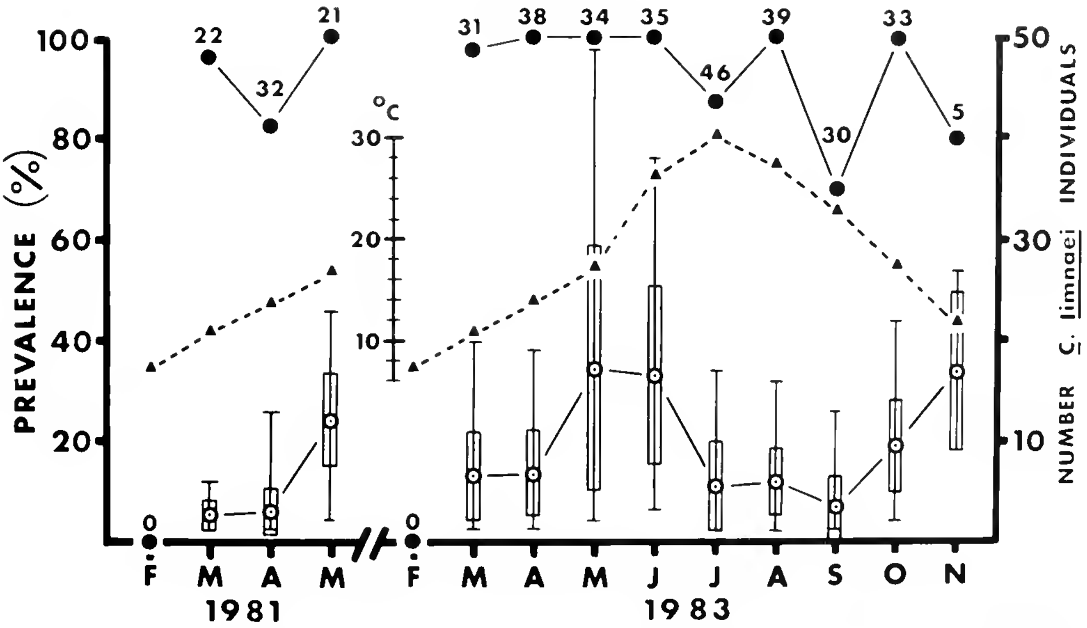

FIG. 1. Monthly prevalence rates (closed circles) and mean intensity levels (open circles) of *Chaetogaster limnaei* in *Helisoma trivolvis*. Numbers above closed circles = sample size; vertical bars = one standard deviation; vertical lines = range; closed triangles = temperature.

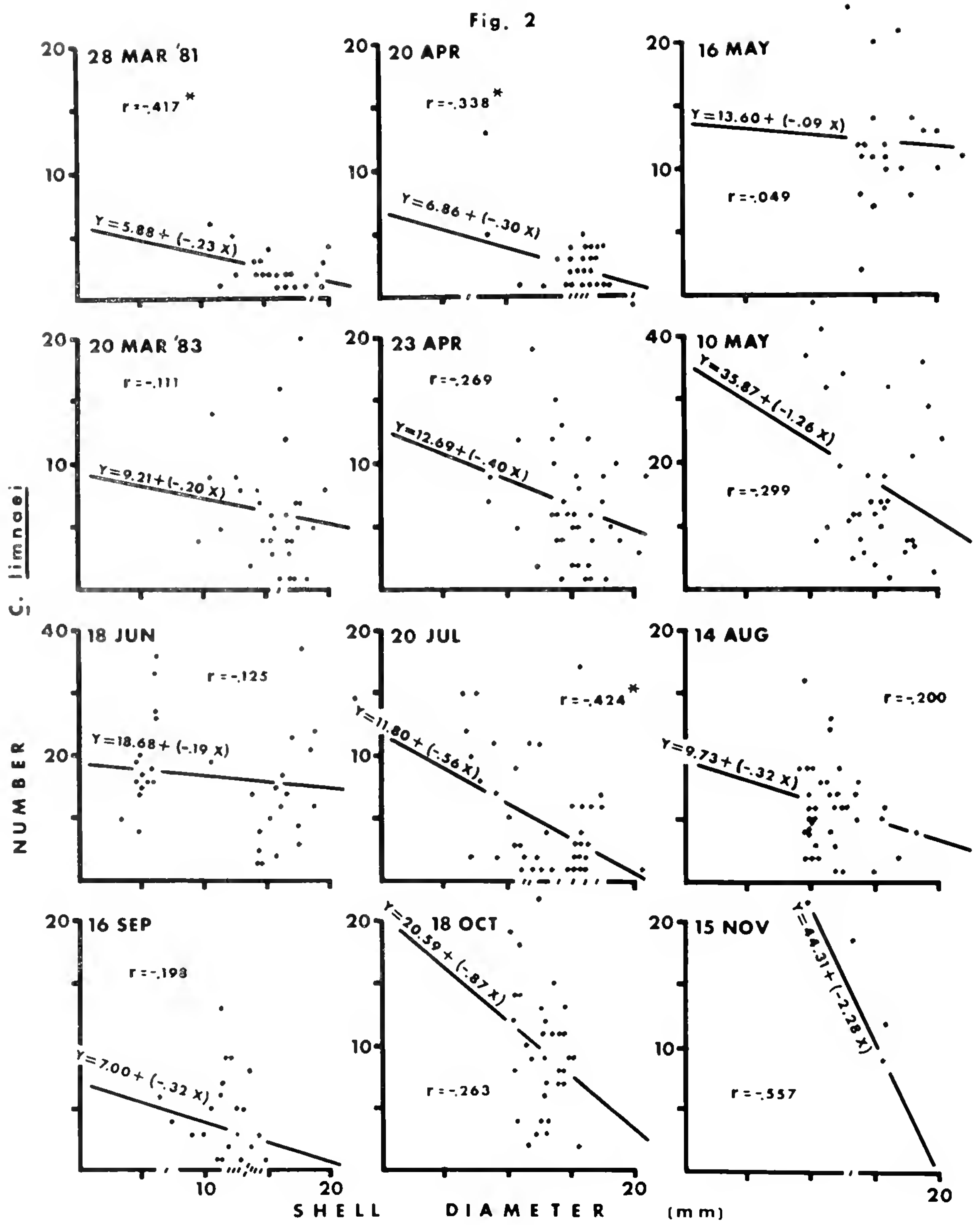

FIG. 2. Scatter diagram depicting relationship between host length and number of *C. limnaei* individuals. Each dot represents a single infected snail. Each slash mark along X-axis indicates non-infected snail. *significantly different from zero at P<.05.

FIG. 3. Ventral view of the oligochaete worm, *Chaetogaster limnaei*. M = mouth; C = chaetae bundle; P = pharynx; E = esophagus; S = stomach; I = intestine.

cal. Since Gruffydd reported that temperature and mean number of *C. l. limnaei* individuals were increasing for those months, temperature, rather than host size, was the more important variable in determining mean number of *Chaetogaster* individuals in the host population. Joy and McBride (1983) noted that prevalence rates and mean intensity levels of *C. limnaei* in the operculate river snail, *Oxytrema canaliculata*, paralleled the temperature curve over an eight month period (April thru November '82). Since they confined their investigation to a single height class (18 to 23 mm), host size had little or no bearing on *C. limnaei* infections. Those investigators did not observe a supression of mean

FIG. 4. Chaetae bundle of the oligochaete worm, *C. limnaei*. (Length of chaeta approximately 100 μ).

intensity levels because of high temperatures, but then their maximum recorded temperature was 26° C (for August '82).

In the present study prevalence was high regardless of host size or temperature, and contrary to the findings of Gruffydd, Buse, and Streit, there was a consistent negative correlation between host size and number of *C. limnaei* present (Fig. 2).

The data suggests that host size is a factor – secondary to temperature – in determining mean intensity levels of *C. limnaei* infections. Still, there is an obvious need for laboratory investigations monitoring *C. limnaei* population dynamics in selected host size classes at different temperature regimes.

Acknowledgments

We are indebted to Mr. Gary Bender for his assistance in collecting snails. Thanks are also extended to Dr. Jarl Hiltunen, U. S. Fish and Wildlife Service; and Dr. Carol Stein, the Ohio State University Musuem of Zoology, for con-

firming our identifications of *Chaetogaster limnaei* and *Helisoma trivolvis*, respectively.

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THE FRESHWATER BIVALVES OF LAKE CHICOT, AN OXBOW OF THE MISSISSIPPI IN ARKANSAS[1]

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ABSTRACT

The 17 bivalve Mollusca of Lake Chicot, Arkansas, were examined from 1977 through 1981 to assess species composition and to compare the Lake Chicot fauna with that of other area lakes. Three other large delta oxbow lakes examined during the same period had 6 or fewer species and fewer individuals of each species. Sediment deposition was 1 to 4 cm annually in all the lakes, but flow-through drainage, percolation from a subsurface sand layer and shoreline wave action kept the sandy littoral zone of Lake Chicot cleared of detrimental deposited sediments. Although numerous environmental factors may have been limiting, fine sediment accumulation in the littoral zone or extreme water level fluctuations were obvious detriments to mollusk habitation in the other lakes. Predominant species in Lake Chicot included Anodonta grandis, Amblema plicata, Lampsilis teres, Plectomerus dombeyana, Potamilus purpuratus, *and* Quadrula pustulosa. *Sixteen of the 17 species found lived in the sandy littoral zone.*

Information on freshwater mollusks inhabiting large oxbow lakes bordering the lower Mississippi River is very limited. Bivalve fauna from Lake Chicot, Arkansas, were collected from 1977 through 1981 as part of an ecological study on the effects of sedimentation on lake systems.

[1] Contribution of the Sedimentation Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Oxford, MS 38655.

Several researchers have collected mollusks from Arkansas waters but most collections have been limited to river systems. Meek and Clark (1914) made extensive collections on the Buffalo River. Wheeler (1914) found 19 species of bivalves in the Cache River, part of which lies in the delta region of northeastern Arkansas. Vanatta (1909) found numerous mollusks in collections from the piedmont and delta reaches of the Ouachita River in south central Arkansas and Louisiana, and Branson (1966) found a

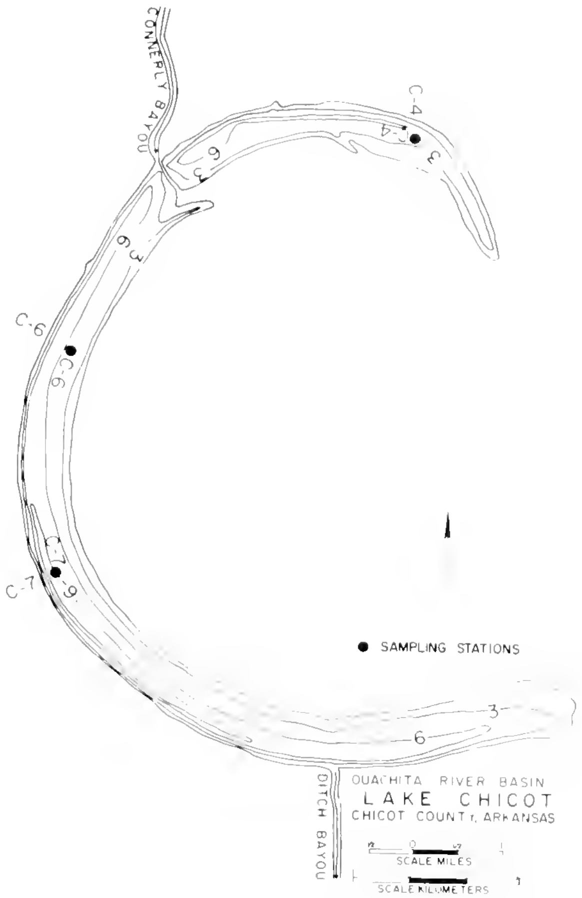

FIG. 1. Morphometric map of Lake Chicot, an oxbow of the Mississippi River in Arkansas.

single species in a strip-pit west of Monroe, Louisiana. The purposes of this study were to investigate mollusk habitation in Lake Chicot, a unique two-part river oxbow lake, and to add distribution data to regional mollusk records.

Study Area

Lake Chicot, a 19.3 km² oxbow of the Mississippi River located in southeastern Arkansas, originally had a small drainage area (> 200 km²) and excellent water quality. A series of events involving channelization, basin enlargement by a major flood in 1927, and construction of the Mississippi River levee enlarged the drainage entering the southern portion of the lake (Fig. 1) via Connerly Bayou to 932 km² by the 1930's. Increased inflow from the enlarged watershed formed a sand spit which partially isolated the northern part of the lake after the 1927 flood. In the 1930's a permanent levee was constructed on the sand spit, dividing the lake into two sections.

Lake Chicot is a typical large river bend with a deep thalweg on the outside of the bend (Fig. 2). A subsurface sand layer creates a sandy littoral zone which drops rapidly into the river bed on the outside of the bend while the littoral zone on the inside of the bend gradually slopes into deeper water.

I collected in littoral and profundal zones at sites C4, C6, C7, Connerly Bayou (inlet) and Ditch Bayou (outlet). I also collected in littoral zones of three river oxbows (Lake Washington, Lake Ferguson, and Lake Bolivar) on the eastern side of the Mississippi River within 100 km of Lake Chicot. Lake Ferguson is directly connected to the Mississippi River and exhibits large water level fluctuations; the other two lakes are isolated from riverine flow.

I collected in shallow reaches by hand sampling, shallow diving, and dragging the bottom substrate with a rake or D-frame dip net.

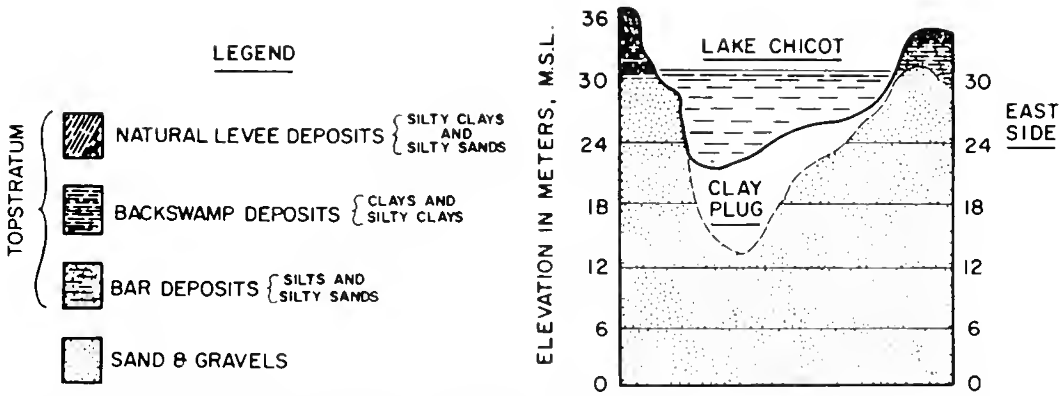

FIG. 2. Cross-section of Lake Chicot, Arkansas, at Station C-7 (Modified after Saucier, 1967).

Deeper water (4 to 9 m) was sampled by Ekman and Peterson grabs. Representatives of all species of clams were verified by David Stansberry of Ohio State University. Voucher specimens are on files at the Mississippi Museum of Natural Sciences, Jackson, MS.

Results and Discussions

Representatives of 17 species of Mollusca were collected from Lake Chicot during the study (Table 1). Predominant species included *Anodonta grandis*, *Amblema plicata*, *Lampsilis teres*, *Plectomerus dombeyana*, *Potamilus purpuratus*, and *Quadrula pustulosa*.

Fingernail clams, *Musculium* sp., were occasionally encountered in profundal regions. Unfortunately all shells were either juvenile or too severly eroded for species identification. All other mollusks were collected from littoral zones, mainly from large clam beds on sandy substrate. Deposited sediments, a problem to clam existence in most delta lakes, did not adversely affect clam populations in Lake Chicot. Percolation from a subsurface sand layer (Fig. 2) and shoreline wave action kept the sandy littoral zone cleared of the 1 to 4 cm/year of detrimental sediments that were normally deposited in other parts of the lake. The isolated north basin of the lake had fewer observed mollusk beds than the main basin but no statistical comparison could be made because of the qualitative nature of sampling procedures.

Three other large delta oxbow lakes examined had six or fewer species (Table 2) and fewer individuals of each species. Lakes Bolivar and Washington had similar sediment problems but exhibited two major differences from Lake Chicot: (1) they were not part of flow-through systems but had only limited inflow and outflow and (2) neither lake exhibited a stable sandy littoral zone because of periodic sedimentation. Specific explanations for fewer species in these two oxbow lakes could include disruptions in glochidia-host relations as exhibited by Yokley (1972) or a disruption of gill processes by settling sediment particles (Ellis, 1936). Although pesticide or heavy metal contamination for intensive agriculture is a possibility, Price and Knight (1977) found that heavy metals were not excessively bioaccumulated in mollusks in Lake Washington. Lake Ferguson had large expanses of sandy shoreline but since it was connected directly to the Mississippi River, water levels fluctuated several meters annually. Although the three lakes on the eastern side of the Mississippi River supported fewer species of mollusks, they were inhabited by four species not found in Lake Chicot: *Anodonta suborbiculata*, *Leptodea fragilis*, *Ligumia subrostrata*, and *Toxolasma parvus*.

TABLE 1. Taxonomic list of Mollusca identified from Lake Chicot, Arkansas from 1977-1981.

Amblema plicata perplicata (Conrad, 1841)
Anodonta grandis grandis Say, 1829
Anodonta grandis corpulenta Cooper, 1834
Corbicula fluminea (Muller, 1774)
Fusconaia flava flava (Rafinesque, 1820)
Lampsilis ovata ventricosa (Barnes, 1823)
Lampsilis radiata hydiana (Lea, 1838)
Lampsilis straminea claibornensis (Lea, 1838)
Lampsilis teres anodontoides (Lea, 1831)
Leptodea laevissima (Lea, 1829)
Plectomerus dombeyana (Valenciennes, 1827)
Potamilus purpuratus (Lamarck, 1819)
Quadrula apiculata aspera (Lea, 1831)
Quadrula pustulosa (Lea, 1831)
Quadrula nanophaena (Lea, 1852)
Villosa lienosa (Conrad, 1834)
Musculium sp.

TABLE 2. Taxonomic list of Mollusca identified from three Mississippi oxbow lakes, 1977-1981.

LAKE BOLIVAR (Bolivar Co., MS)
Anodonta grandis corpulenta Cooper, 1834
Anodonta grandis grandis Say, 1829
Anodonta suborbiculata Say, 1831

LAKE FERGUSON (Washington Co., MS)
Anodonta grandis grandis Say, 1829
Anodonta suborbiculata Say, 1831
Corbicula fluminea (Müller, 1774)
Leptodea fragilis (Rafinesque, 1820)
Quadrula apiculata aspera (Lea, 1831)
Toxolasma parvus (Barnes, 1823)

LAKE WASHINGTON (Wash. Co., MS)
Anodonta grandis grandis Say, 1829
Ligumia subrostrata (Say, 1831)
Quadrula apiculata (Say, 1829)
Toxolasma parvus (Barnes, 1823)

Summary

Optimal habitat conditions allowed abundant growth of 17 species of clams in Lake Chicot, AR where basin morphometry produced a natural maintenance of sandy littoral zones. Three other oxbow lakes on the eastern sides of the

Mississippi River had less suitable littoral conditions and supported six or fewer species because of water level fluctuations, lack of flow, and/or sediment accumulation. They were, however, inhabited by four species not found in Lake Chicot.

Acknowledgments

This paper is a contribution of the USDA Sedimentation Laboratory, Agricultural Research Service. Research on Lake Chicot was done in cooperation with the U.S. Army Corps of Engineers, Vicksburg District. The author wishes to thank Scott Knight for field assistance and Paul Hartfield, Invertebrate Curator, Mississippi Museum of Natural Sciences and Dr. David Stansbery, Ohio State University for species verification. Dr. J. R. McHenry was the USDA principal investigator over the entire Lake Chicot project.

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A NEW *HUMBOLDTIANA* (PULMONATA: HELMINTHOGLYPTIDAE) FROM EXTREME EASTERN CHIHUAHUA, MEXICO

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ABSTRACT

A new species of pulmonate land snail, described from shells, is assigned provisionally to the helminthoglyptid genus Humboldtiana. *The shells are unusual for the genus in being relatively small, depressed, smooth and glossy. Types were collected in the Sierra Santa Eulalia, Chihuahua, Mexico.*

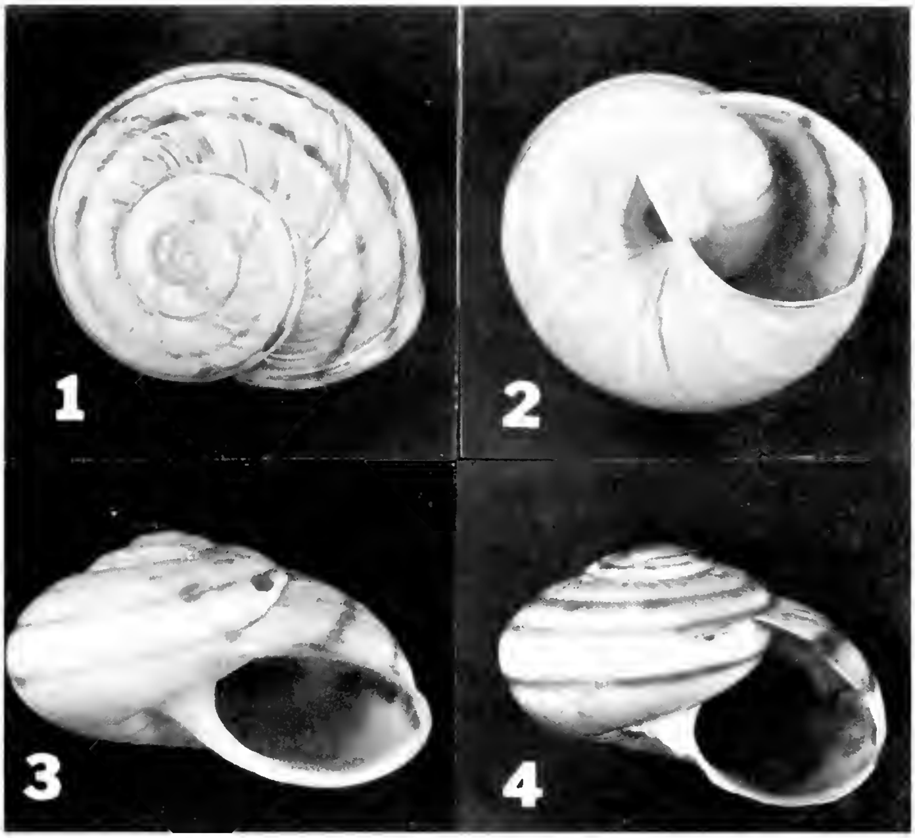
The species described herein was collected on 23 March 1982 by Mr. Wally Lippincott (U.S. Department of Agriculture, Lake Worth, FL), who kindly sent them to me in June 1982. The lot consisted of four specimens, one of which contained a desiccated body. At first glance, the general configuration of the shells suggested a member of the genus *Sonorella*. However, despite the atypical shell morphology, other features seem to indicate that the species belongs to the genus *Humboldtiana*.

Humboldtiana eulaliae, *new species*

(Figs. 1-4)

Diagnosis: A relatively small *Humboldtiana*, with depressed shell, rounded peripherally, low spire and slightly reflected outer lip. The shell exhibits 3 brownish spiral bands, very weak growth lines and is smooth and glossy.

Description of Holotype: Shell depressed, 28.1 mm in diameter and 17.2 mm high; smoothly rounded peripherally; spire low, rising gradually to height of 8.5 mm with angle of *ca.* 135°; 4.3



FIGS. 1-4. *Humboldtiana eulaliae* new species, Metcalf, from the west side of the Sierra Santa Eulalia, eastern Chihuahua, Mexico. **1-3**, holotype (28.1 mm in diameter), **4**, paratype *a*.

whorls, with body whorl moderately descending; aperture slightly ovate, 13.0 mm wide and 10.6 mm high, inclined at an angle of *ca.* 45° to the vertical, columellar portion of peristome covering about ⅓ of the umbilicus and outer portion forming a slightly thickened and reflected lip; first 2 whorls light tan and glossy with exceedingly fine growth lines except stronger on inner part of whorl near the suture on second whorl; after second whorl, low but clearly distinguishable growth lines cross entire whorl, occurring both dorsally and ventrally, but remaining low and weakly developed, giving the shell a relatively smooth appearance, overall. The shell is empty and slightly bleached; shell color beyond the embryonic whorls whitish except for presence of 3 brownish bands; uppermost band originating as faint gray, interrupted segments in center of whorl 3 and becoming more continuous and brownish in color on whorl 4; middle band originating as continuous tan band alongside suture at 2.1 whorls; lower band first observed slightly below periphery of body whorl near upper terminus of lip; all bands most strongly developed on terminal portion of body whorl near reflected lip.

Paratypes: Three shells (*a*, *b*, and *c*) were obtained in addition to the holotype. Measurements of these, in order *a*, *b*, *c*, are: width: 26.7, 24.9, 20.8; height: 16.9, 14.8, 12.5; whorls: 4.1, 3.6, 3.7. Shells *a* and *c* are fresh and shell *c* (a juvenile) contains a desiccated body. Both have broken lips and *c* retains fragments of a calcareous epiphragm. In the month of March (dry season) it was, no doubt, sealed by the epiphragm to a stone. Unlike the holotype, shells *a* and *c* have not suffered bleaching and have a light grayish brown background color. The brownish bands are slightly wider and darker in color than in the holotype (see specimen *a* in Fig. 4). Faint growth lines are better discerned on the embryonic whorls than in the holotype; however,

the shells, overall, have a smooth and slightly glossy appearance. Shell *b* is greatly bleached and coated with calcium carbonate dorsally. It appears to be fossil or subfossil.

Etymology: The epithet *eulaliae* refers to the saint after which is named the Sierra Santa Eulalia, the type locality.

Type locality: The types and paratypes are reported by Mr. Wally Lippincott as being taken on the west side of the Sierra Santa Eulalia in easternmost Chihuahua, Mexico, near the border with the state of Coahuila, in an area centering around 27°12′N; 103°47′36″W. On the DETENAL 1:50,000 topographic quadrangle for Guimbalete (G-13, B-44) the locality is indicated by the collector as along walls of a canyon debouching southwestward about midway of the Santa Eulalia range. The mouth of the canyon is 1.3 km E of "El Pinolero" and 7.5 km N and 1.5 km E of "Penoles" on the Guimbalete quadrangle. The canyon is *ca.* 2.5 km long, heading at *ca.* 1650 m and debouching at *ca.* 1250 m. Mr. Lippincott writes (*in litt.*, 26 June 1982): "Within the canyon the snails were taken from the south facing ledges. These ledges were approximately 10-20 meters above the dry creek bed. They were characterized by smooth, broken up stones interspersed between talus areas. The snails were taken from under the smooth rocks."

Disposition of Types: Holotype: National Museum of Natural History, USNM 820297; Paratypes: University of Arizona 6262 (shell *a*), University of Texas at El Paso 8785 (shells *b* and *c*).

Discussion: The mountains of eastern Chihuahua and adjacent Coahuila are almost unknown malacologically. In the region, two species have been described that are provisionally assigned to *Humboldtiana*: the present one and *H. plana* Metcalf and Riskind, 1976. Shells of both these species are atypical of *Humboldtiana* in general. Further collecting in these areas will probably reveal other new species and eventually should lead to an understanding of the relationships of these unusual shells.

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FRESHWATER MUSSELS (BIVALVIA: UNIONIDAE) OF MONROE COUNTY, WEST VIRGINIA

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ABSTRACT

A survey of the mussel fauna of Monroe County, West Virginia, was conducted during the spring of 1983 and 1984. This survey included samples from the Greenbrier River, Indian Creek, and South Fork of Potts Creek. Twelve species of unionid mussels and Corbicula fluminea *were collected from these three watersheds, including a new state record,* Canthyria collina, *which is found in the South Fork of Potts Creek.*

Information on the extant mussel populations of West Virginia was extremely limited until the past decade. Mussel surveys conducted during this period, especially in the past five years, has greatly enhanced this information. This study was performed in conjunction with a statewide

inventory of mussels conducted by the West Virginia Department of Natural Resources, Division of Water Resources. This inventory has investigated approximately fifty percent of the state's streams with known mussel populations (Schmidt and Zeto, 1984), yielding 49 naiad species. Recent studies in the state have been conducted by Schmidt, Zeto and Taylor (1983) on the Little Kanawha River Basin, Zeto (1982) on the Monongahela River Basin, and Clarke (1982) on the upper Kanawha River. Taylor and Hughart (1981), Morris and Taylor (1978), and Taylor (1980) have also conducted taxonomic surveys on the Elk, Kanawha, and Ohio rivers, respectively. The only recent published studies performed in the vicinity of Monroe County were those conducted by Bates (1971) and Stauffer, Hocutt, and Markham (1980) on New River. The U.S. Fish and Wildlife Service also conducted a 1983 mussel survey in the study area (New and Bluestone Rivers) in conjunction with the U.S. Army Corps of Engineers, Huntington District. An earlier survey of mussels from the study area which has not been published upon was conducted by Stansbery (pers. comm.) in 1964. Many of the species recorded in this study represent the first published mussel records for the respective watersheds.

Study Area

Monroe County is located in the extreme southeast portion of West Virginia. It is bordered to the north by Greenbrier County and by Summers and Mercer counties to the west. Monroe County is bordered by the State of Virginia to the south and east. The majority of the county (the western half) lies in the New River basin. The northern and central portions of the county are in the Greenbrier River drainage, while the extreme eastern section of the county is in the James River (Virginia) drainage. The streams specifically concerned in this study are the Greenbrier River and Indian Creek of New River, and Potts Creek of James River.

Site 1 is located on the Greenbrier River off State Route 3, 3.22 kilometers southwest of Alderson, Greenbrier County (37°41′56″N × 80°40′07″W). The river at this location lies entirely in Monroe County for a very short distance of approximately 0.8 kilometers. Greenbrier River originates in Randolph County and flows in a generally southwesterly course across Pocahontas, Greenbrier, Monroe and Summers counties to its confluence with the New River at Hinton, Summers County. Greenbrier River is 246.33 kilometers long and falls at an average of 3.14 meters per kilometer. The West Virginia Department of Natural Resources Greenbrier River Basin Plan (1983) states that excellent water quality exists in the river.

Indian Creek rises in the limestone sinks of south-central Monroe County. The stream flows in a general westerly direction to its confluence with New River near Junta, Summers County. Indian Creek is 54.74 kilometers long. According to the West Virginia Department of Natural Resources New River Basin Plan (1983), the stream receives pollution from cropland erosion and the inadequate disposal of human and/or animal wastes. Three sites were surveyed on Indian Creek in Monroe County. These are in upstream sequence: site 2a at County Route 23 bridge, 1.6 kilometers north of Red Sulphur Springs (37°31′44″N × 80°46′13″W); site 2b off County Route 23, 6.44 kilometers northeast of Red Sulphur Springs (37°33′27″N × 80°45′18″W) and site 2 c off State Route 122, 2.42 kilometers west of Greenville (37°33′11″N × 80°42′33″W).

Potts Creek heads in the southwestern corner of Monroe County and flows northeastward into Craig County, Virginia. The stream is in the James River drainage. The entire portion of the Potts Creek watershed lying in West Virginia was surveyed for freshwater mussels, however mussels were found only in the South Fork.

The South Fork of Potts Creek is 9.34 kilometers in length and falls at a rate of 21.66 meters per kilometer. Mussels were located at two sampling points on South Fork. Site 3a is located off County Route 17, 1.6 kilometers northeast of Waiteville (37°29′03″N × 80°24′50″W), while site 3b is located further upstream off County Route 17, 0.8 kilometers west of Waiteville (37°28′21″N × 80°25′54″W).

Figure 1 depicts sampling sites where mussels are located.

Methods

All sampling sites were examined during normal or slightly low flow conditions. Each site consisted of at least one riffle and one pool. The sites were sampled by walking the banks looking

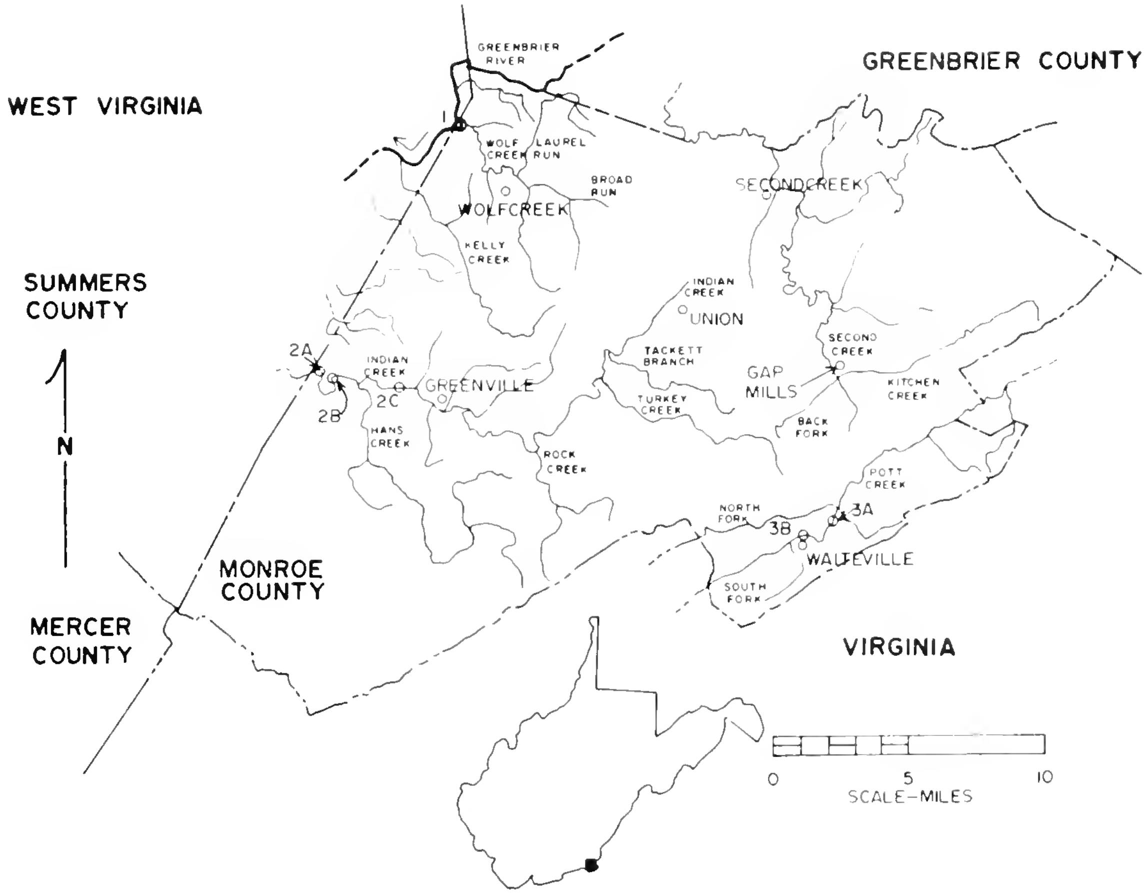

FIG. 1. Mussel collection sites in Monroe County, West Virginia. Localities are identified in text.

for shell material, while water scopes were used in the streams to locate live specimens.

As material was collected in the field, a preliminary species list was compiled on site. Live specimens were sacrificed and retained only if suitable dead material was not available. All collected material was bagged, labeled and returned to the lab for positive identification. Dr. David Stansbery (The Ohio State University) aided in the identification of difficult specimens and confirmed all others. Voucher specimens have been accessioned in the Ohio State University, Museum of Zoology.

Results and Discussion

A total of 12 species of freshwater unionid mussels and *Corbicula fluminea* were collected during this Monroe County survey (Table 1). Greenbrier River supported seven species of mussels, the dominant species being *Elliptio dilatata*, *Cyclonaias tuberculata* and *Actinonaias ligamentina carinata*. Other species in Greenbrier River include *Alasmidonta marginata*, *Tritogonia verrucosa*, *Lampsilis ventricosa* and *Lampsilis fasciola*. All seven species were collected by Stansbery in 1964, however Bates reported "negative results" for the Greenbrier River in his 1971 survey. Apparently, the results of this latter survey were erroneously reported, as there are currently dense populations of naiads in the Greenbrier River representing numerous age classes. Indian Creek also contained seven species of mussels, with the population being greatly dominated by *Elliptio dilatata*. Other species collected from Indian Creek include *Anodonta grandis grandis*, *C. tuberculata*, *Toxolasma parvus*, *Villosa iris iris*, *L. ventricosa* and *L. fasciola*. Potts Creek con-

TABLE 1. Freshwater Mussels of Monroe County, West Virginia, 1983-1984.

Species	Site Number					
	1	2a	2b	2c	3a	3b
Anodonta grandis grandis (Say, 1829)		X				
Strophitus undulatus undulatus (Say, 1817)					X	X
Alasmidonta marginata (Say, 1818)	X					
Tritogonia verrucosa (Raf., 1820)	X					
Cyclonaias tuberculata (Raf., 1820)	X	X	X			
Elliptio dilatata (Raf., 1820)	X	X	X	X		
Actinonaias ligamentina carinata (Barnes, 1823)	X					
Toxolasma parvus (Barnes, 1823)			X			
Villosa iris iris (Lea, 1829)		X				
Lampsilis ventricosa (Barnes, 1823)	X	X	X			
Lampsilis fasciola (Raf., 1820)	X	X	X	X		
Canthyria collina (Conrad, 1837)					X	X
Corbicula fluminea (Muller, 1774)	X	X	X	X		

tained two species of unionids of relative equal abundance. These species are *Strophitus undulatus undulatus* and *Canthyria collina*. None of the species collected is currently listed as endangered, however *Canthyria* (alias *Fusconaia*) *collina* is currently listed in the Federal Register (1984) by the U.S. Fish and Wildlife Service for possible listing as a threatened or endangered species.

Greenbrier River and Indian Creek both contained seven species of Unionidae, however only four of these (*C. tuberculata*, *E. dilatata*, *L. ventricosa* and *L. fasciola*) were common to both drainages. This variation in species is probably attributed to the difference in habitat between the two watersheds.

Greenbrier River is a much larger water body possessing fairly turbulent water, with a substrate consisting mainly of rocks, cobble and sand. Indian Creek is smaller in size with calm water. There is also much more silt in the substrate of Indian Creek due to cropland erosion.

The mussel population existing in the South Fork of Potts Creek is somewhat a surprise, since this is an extreme headwater stream which usually are non-supportive of mussels. One of the species, *Canthyria collina*, found in this stream is restricted to the James River drainage, while *Strophitus undulatus undulatus* is common to both the Atlantic Costal and Mississippian mussel faunas. *Canthyria collina* represents the first record for this mussel in West Virginia.

Acknowledgments

The authors would like to extend their great appreciation to Dr. David Stansbery for his cooperation and assistance in identification. We would also like to thank Lee Spencer and Jack Mumaw for their assistance in collecting.

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BERMUDA MARINE MOLLUSK TYPE SPECIMENS TRANSFERRED TO THE SMITHSONIAN

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Recently, a number of type specimens of mollusks described by William Healey Dall and Paul Bartsch were transferred from the Bermuda Aquarium, Museum and Zoo, Flatt's, Smith's Parish, Bermuda, to the collection of Recent Mollusks, Department of Invertebrate Zoology, National Museum of Natural History, Washington, D.C.

Since these type specimens were originally mentioned as being in the Bermuda Museum, or in the collection of Mr. Arthur Haycock, of Bermuda, it is necessary to put on record their new location for the benefit of malacologists who may wish to examine them in connection with research projects. In some cases the numbers of specimens per species sent from the Bermuda Museum (Haycock Collection) and labeled as Cotypes (= Syntypes or where a Holotype or Lectotype can be distinguished, Paratypes or Paralectotypes) exceed the number originally mentioned by Dall and Bartsch in their publications. It is probable that Haycock did not originally send or mention all the specimens he had available for examination.

The types of the following species are involved and are listed in order of their publication.

Argyrodonax haycocki Dall, 1911:86 (Bermuda: Lectotype USNM 842643; Paralectotypes USNM 783533). The type lot was described by Dall as consisting of one complete specimen and a single additional valve all in the collection of Arthur Haycock, Bermuda [later in the collection of the Bermuda Museum]. In 1979 NMNH received from the Bermuda Museum two single and unrelated valves of this species labeled as Syntypes. Recently a complete specimen marked "type" was received that matches Dall's description and measurements and it is here designated the Lectotype. *Argyrodonax haycocki* originally assigned by Dall to the family Mesodesmatidae, has the dentition and sculpture of *Cumingia* and therefore appears to belong in the family Semelidae.

Columbella somersiana Dall and Bartsch, 1911:278, pl. 35, fig. 2 (Bermuda; Holotype USNM 842644). This species originally was described from a single specimen. In 1912 an additional specimen, so named, was received

from Haycock, and added to the NMNH collection (USNM 251405, 13.7 mm). The specific name was considered a synonym of *Columbella mercatoria* (Linné, 1758) by Abbott (1974), and by Radwin (1977).

Aclis bermudensis Dall and Bartsch, 1911:278, pl. 35, fig. 5 (Bermuda; 2 Paratypes USNM 228692). Although the authors indicated that the Holotype is in the Bermuda Museum, no specimens of this species were included with the recent transfer from that source. One of the two Paratype specimens was illustrated (Bartsch, 1947:2-3, pl. 1, fig. 2) and may be designated as a replacement if the Holotype cannot be found.

Cerithiopsis ara Dall and Bartsch, 1911:282, pl. 35, fig. 1 (Bermuda; 3 Syntypes USNM 221612). 14 additional Syntypes were transferred recently to NMNH from the Bermuda Museum (USNM 842645).

Cerithiopsis pesa Dall and Bartsch, 1911:283, pl. 35, fig. 10 (Bermuda; Holotype USNM 221616). 10 additional Paratypes were recently transferred to the NMNH from the Bermuda Museum (USNM 842646).

Cerithiopsis vicola Dall and Bartsch, 1911:284, pl. 35, fig. 12 (Bermuda; Holotype USNM 842647). Although originally stated by Dall and Bartsch (1911, p. 285) to be based on a unique specimen, the Holotype and 2 additional specimens (Paratypes USNM 842648) were recently transferred to NMNH from the Bermuda Museum.

Cerithiopsis io Dall and Bartsch 1911:285, pl. 35, fig. 3 (Bermuda; Lectotype USNM 221615). The figured specimen is here designated as the Lectotype. Although only 1 additional specimen was mentioned as being in the Bermuda Museum, 4 specimens (Paralectotypes USNM 842649) were recently transferred to the NMNH from the Bermuda Museum.

Type specimens of remaining species described by Dall and Bartsch 1911, were already in the NMNH collection at the time of the transfer described above, and several, also, were originally said to be represented by Syntypes or Paratypes in the Bermuda Museum as follows:

Mitra haycocki Dall and Bartsch, 1911:277, pl. 35, fig. 7 (Bermuda; Syntypes Bermuda Museum; also USNM 221617). [*Is Mitrolumna biplicata* (Dall, 1889), Turridae, (Abbott, 1974, p. 269)].

Turbonilla (Careliopsis) bermudensis Dall and Bartsch, 1911:279, pl. 35, fig. 4 (Bermuda; 3 Syntypes: USNM 221614).

Turbonilla (Strioturbonilla) peilei Dall and Bartsch, 1911:280, pl. 35, figs. 9, 9a (Bermuda; 2 Syntypes: 1 in Bermuda Museum and 1 in USNM 221610).

Turbonilla (Strioturbonilla) haycocki Dall and Bartsch, 1911:280, pl. 35, fig. 6, 6a (Bermuda; 4 Syntypes: 2 in Bermuda Museum and 2 in USNM 221611).

Cerithiopsis movilla Dall and Bartsch, 1911:281, pl. 35, fig. 11 (Bermuda; 2 Syntypes USNM 221613).

Fissuridea bermudensis Dall and Bartsch, 1911:286, pl. 35, fig. 8 (Bermuda; Syntypes in Bermuda Museum and USNM 221618). [a valid *Diodora* (Farfante, 1943, *Johnsonia*, vol. 1, no. 11, p. 10)].

Odostomia (Chrysallida) niobe Dall and Bartsch, 1911:286 (Bermuda; USNM 223284).

Ischnochiton (Stenoplax) bermudensis Dall and Bartsch 1911:287 (Bermuda; Holotype USNM 223354). [*is Stenoplax rugulata* (Sowerby, 1832) (Abbott, 1974, p. 397).]

Several additional species were described by Paul Bartsch (1911) from collections supplied by Arthur Haycock, from Bermuda. The types of at least one of these species also were originally shared between the Bermuda Museum and NMNH, but no additional specimens were transferred to the latter:

Cerithiopsis hero Bartsch, 1911:303 (Bermuda; USNM 226450).

Cerithiopsis cynthia Bartsch 1911:304 (Bermuda; USNM 226449).

Cerithiopsis iontha Bartsch, 1911:304 (Bermuda; Bermuda Museum and USNM 226451).

Triphora bermudensis Bartsch, 1911:306 (Bermuda; USNM 226452). [*Is Triphora turristhomae* (Holten, 1802) (Abbott, 1974, p. 111).]

Abbreviations used here:

NMNH – National Museum of Natural History.
USNM – United States National Museum, collections of which are in NMNH.

Acknowledgments

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transfer. Harald A. Rehder and Richard S. Houbrick read and criticized the manuscript.

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PRODUCTION OF IMMATURE *CORBICULA FLUMINEA* (BIVALVIA: CORBICULIDAE), IN LAKE NORMAN, NORTH CAROLINA

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ABSTRACT

The annual production of the immature specimens of the Asiatic clam, Corbicula fluminea, *was determined in littoral and sublittoral zones of Lake Norman, North Carolina, from February 1978 through January 1979.* C. fluminea *had a growing season greater than nine months, from 22 March 1978 to 8 January 1979. The higher mean annual production (516 mg/m²) and P/B ratio (26.4) of* Corbicula *occurred in the littoral zone, while mean annual production and P/B of* Corbicula *in the sublittoral zone were 182 mg/m² and 16.4, respectively. The littoral zone had the higher mean* Corbicula *biomass (20 mg/m²) and density (3040/m²) compared to the mean* Corbicula *biomass (11 mg/m²) and density (891/m²) in the sublittoral zone.*

The Asiatic clam, *Corbicula fluminea* (Müller, 1774), (Bivalvia: Heterodonta: Corbiculidae) was first discovered in the United States in 1938, on the shoreline of the Columbia River in Washington (Burch, 1944). Since 1938, *C. fluminea* has successfully overcome physical and ecological barriers to extend its range from the west coast to the east coast of the United States (Rodgers *et al*, 1979). *Corbicula fluminea* was first found in Lake Norman, North Carolina, in August 1972 (T. W. Yocum, pers. commun.). Since that time, *C. fluminea* has greatly increased in number; from 1974 through 1978, *C. fluminea* density increased approximately sixty-fold in Lake Norman (Duke Power Company, unpubl. data). Their biomass increased from 0.1% (January 1974) to 85% (October 1978) of the total benthic biomass collected in the sublittoral zone of Lake Norman.

Corbicula fluminea are simultaneous hermaphrodites and incubate their young within the inner demibranch of the ctenidium. Reproduction and release of veligers (non-swimming planktotrophic larvae) occurs when water temperatures are above 16°C (Eng 1979), with an average daily release of 387 (spring) and 320 (fall) veligers per clam (Britton and Fuller 1980). They have a life span up to seven years and can attain a shell length of 5.0 to 6.5 cm (Britton and Fuller 1980; Ingram 1959; Pool and Tilly 1977).

Small clams and veligers are easily taken into industrial water systems where untreated water

is used. When the clams are about 1.5 mm in length, they can attach to the substrate with their byssus (Goss and Cain 1975). The electric generating industry is the single largest non-consumptive user of water, and has encountered numerous problems with the clams. The most serious problem is the fouling of cooling condensers, which causes high back pressure on the turbines and consequently reduces turbine efficiency. Cherry *et al* (1980) state that the most effective treatment is mechanical removal of shells and sediments. In some cases, the fouling is so extensive that it can only be remedied by closing down the generating unit and manually removing the clams from the condensers (Goss and Cain 1975). In addition, problems can occur in the fire protection service water and emergency reactor cooling systems (Smithson, 1981). Because of their potential to clog waterlines, interest in the biology of *C. fluminea* has been stimulated by industries that use raw water (Goss and Cain 1975).

Study Area

A one-year study of the production of *C. fluminea* in Lake Norman was initiated in February 1978. *C. fluminea* occurred primarily in the littoral and sublittoral zones and were near-absent in the profundal zone; therefore, production was estimated only for the littoral and sublittoral zones of Lake Norman. Production has been defined by Clarke (1946) as the amount of tissue elaborated per unit area, per unit time, regardless of its fate. The objectives of this study were to:

1) describe the life cycle of *C. fluminea* in Lake Norman.

2) estimate the production, density, and production/biomass ratios of *C. fluminea* in Lake Norman, in four areas of the lake, at two depth zones, littoral (~4 m) and sublittoral (~8 m).

Lake Norman (36°26′N, 80°56′W) is located 27 km north-northwest of Charlotte, North Carolina. The lake was impounded in 1963 and has a total surface area of 13,156 ha, a maximum depth of 36.6 m, and a mean depth of 10.3 m at full pond. Lake Norman is the source of cooling water for two electric generating plants, Marshall Steam Station and McGuire Nuclear Station, and is a source of water for Cowans Ford Hydroelectric Station (Duke Power Company 1980). Four locations were selected at both littoral (~4 m) and sublittoral (~8 m) depths (represented by X.7 and X.6 location numbers, respectively) (Fig. 1). These locations are expected to receive maximum (Location 4), minimum (Locations 2 and 6), and no (Location 8) thermal effluent from McGuire Nuclear Station (Duke Power Company 1976).

Methods and Materials

Triplicate Petersen grab samples (258 cm² each) were taken at all locations at four week intervals from 23 February 1978 through 25 January 1979 (13 sampling periods). The samples were washed in Wildco sieve buckets (212-μm mesh) and preserved in 70% ethanol containing 0.25 g/l rose bengal stain. *Corbicula* were sorted from the bottom samples in the laboratory and were measured to the nearest 0.5 mm using an ocular micrometer. Shell lengths were measured at their greatest anteroposterior dimension across the valves. All specimens in each size-class (0.5-mm increments) of *Corbicula* were first removed from 70% ethanol, shucked from their shells, rehydrated in distilled water, removed from the distilled water, blotted dry, placed in a pre-weighed crucible, dried at 105°C for 24 hr, cooled, and reweighed to the nearest

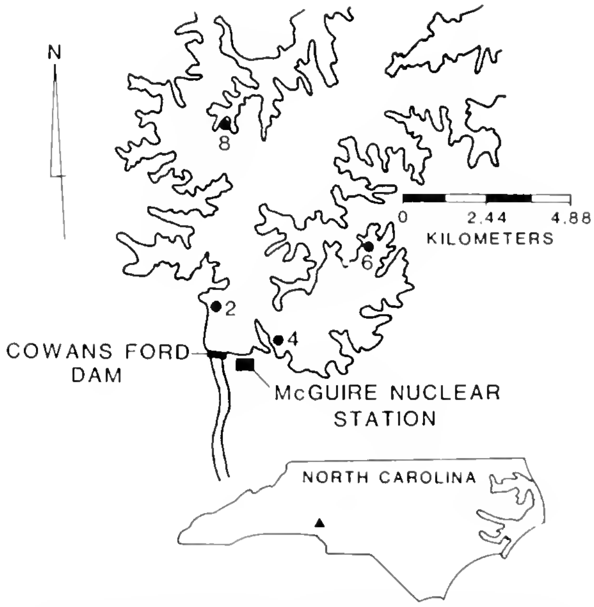

FIG. 1. Locations sampled for *Corbicula* during the production study on lower end of Lake Norman, North Carolina.

0.01 mg on a Mettler (Model H542) balance. A body length-dry weight least squares regression equation was calculated from these data.

Production estimates, using dry weights, were calculated using the size-frequency method (Hynes 1961, 1980; Hynes and Coleman 1968) as modified by Hamilton (1969). The estimates were based on all size classes from the smallest occupied size class to the largest size class containing substantial numbers (Waters 1977). Therefore, I used the 6.0-mm size class as the maximum size class. The annual P/B ratio was computed as the annual production estimate divided by the mean standing crop biomass. This value theoretically indicates how many times per year the mean population biomass is replaced.

Sediment temperatures were taken with a YSI Model 46 TUC tele-thermometer at every location and sampling period.

Differences in production estimates could not be statistically tested, so differences in the *C. fluminea* densities that the production estimates were calculated from were tested with an analysis of variance procedure after densities were logarithmically transformed (Elliott 1977). An F-max test (Sokal and Rohlf 1981) indicated that variances of *C. fluminea* mean densities (N = 39 samples) for each location were heterogeneous at the littoral locations (F-max = 2.76; $p<.05$) and were homogeneous at the sublittoral locations (F-max = 1.43; $p>.05$). Heterogeneous variances violates an assumption of the parametric ANOVA, but Keppel (1973) stated that when equal sample sizes were used, the distortion of the F distribution was relatively slight. Since sample sizes were equal, a one-way ANOVA (Sokal and Rohlf 1981) was performed to determine if there were significant differences among locations. Significant differences in *C. fluminea* mean densities among locations were tested for using Duncan's Multiple Range Test (Sokal and Rohlf 1981). Data analyses were done using the Statistical Analysis System (Barr *et al.* 1979).

Results

Life Cycle

The number of 0.5-1.0 mm size classes dominated the density throughout this study for both littoral and sublittoral zones (Fig. 2). The proportion of 0.5 mm clams increased in June, reflected reproduction in May, which possibly continued through late November (Fig. 2). Aldridge and McMahon (1978) found that veligers released in late spring and early summer

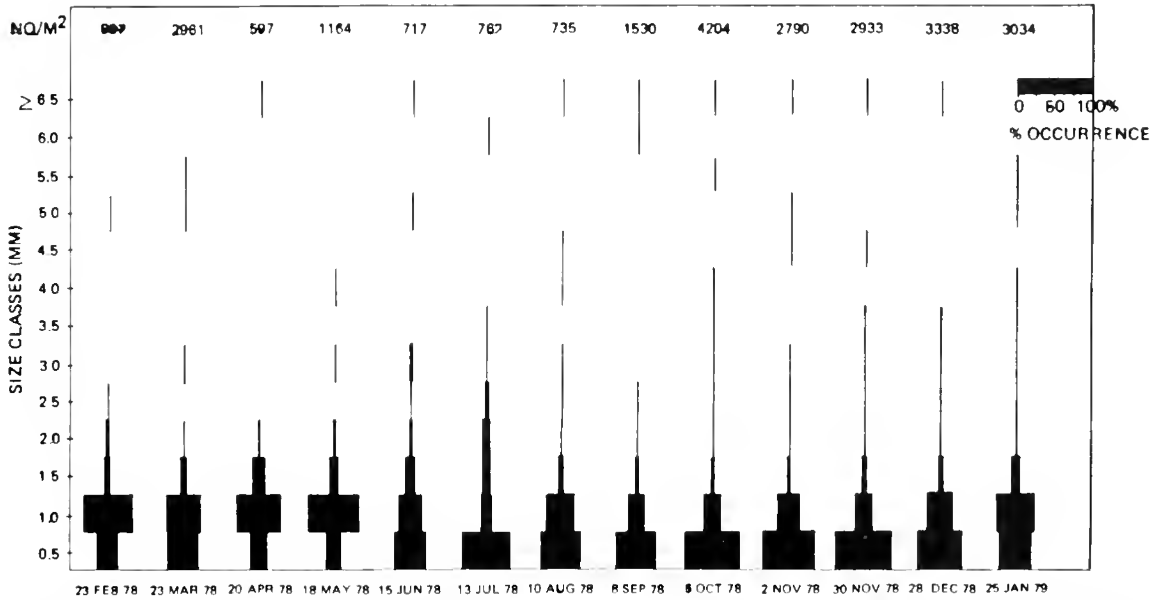

FIG. 2. Length-frequency histograms for *Corbicula fluminea* collected in Petersen grab samples from the combined littoral and sublittoral zones of Lake Norman (densities are shown as percent occurrence in each size class collected per month).

are able to reach sexual maturity by the fall. The high density of small clams (≤0.5 mm) from September through November possibly indicates that higher reproduction occurred in the fall (Fig. 2). The high reproductive ability of *C. fluminea* is offset by the high mortality which is shown to have occurred in the early stages of growth (veliger to 6.0 mm) preventing all but a few clams from reaching sexual maturity (Fig. 2).

Sediment temperatures above 8°C (biological zero for *C. fluminea*) (Duke Power Co., unpubl. data) occurred from 1 April 1978 through mid January 1979 in the littoral and sublittoral zones in Lake Norman (Fig. 3).

Regression Analysis

The least squares regression equation $\ln W = -5.11 + 2.98 (\ln L)$, where ln W is the natural logarithm of dry weight in milligrams and ln L is the natural log of body length in millimeters, was used to calculate dry weight from body length. This relationship accounted for 99% (R^2) of the variance, and the slope was significantly different from zero ($F_{(1,19)} = 3592.0$; $P<0.0001$).

Production Estimates

Production estimates were multiplied by two to account for two generations produced each year (Hamilton 1969). The bivoltine life cycle of *C. fluminea* was determined from literature research (Aldridge and McMahon 1978; Sinclair and Isom 1963) and data from the *C. fluminea* growth study in Lake Norman (Duke Power Co., unpubl. data). The littoral zone had the higher mean annual density (3040/m²) and production (516 mg/m²/yr) (Table 1). The littoral locations with the highest and lowest densities of *C. fluminea* were Locations 2.7 and 4.7 corresponding to the highest (732 mg/m²/yr) and lowest (80 mg/m²/yr) production estimates, respectively (Table 1). The average P/B in the littoral zone was 26.4 and ranged from 14.8 to 34.2 (Table 1). There were overall significant density differences in the littoral zone ($F_{(3,152)} = 13.58$; $P<0.0001$). Locations 4.7 and 2.7 were significantly different from each other and from both 6.7 and 8.7 (Table 2). However, Locations 6.7 and 8.7 did not differ from each other (Table 2).

The mean annual density of *C. fluminea* in the sublittoral zone was 70.7% less than that in the

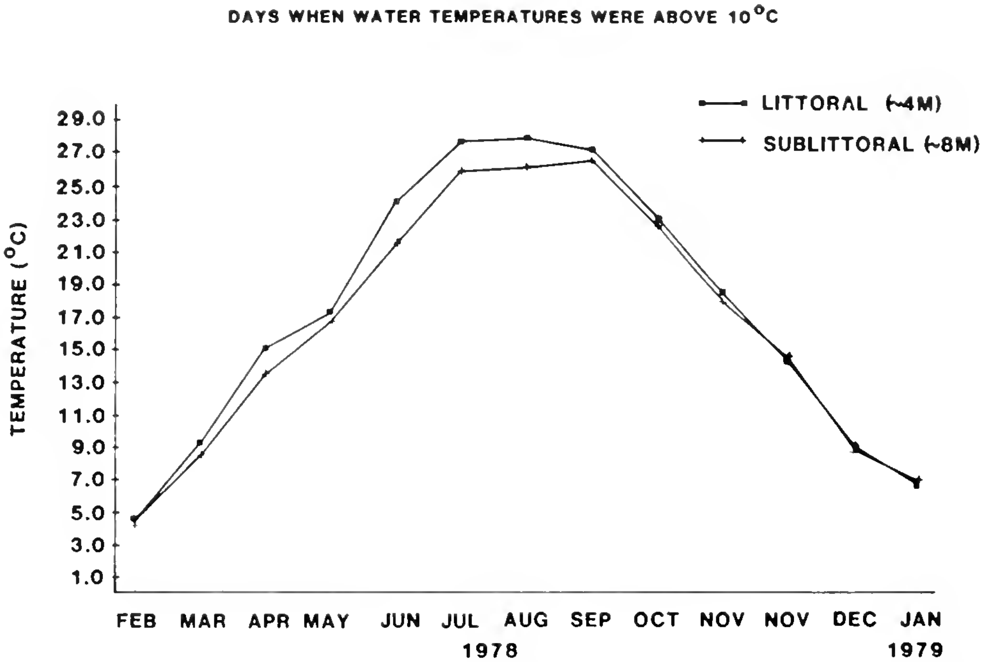

FIG. 3. Mean monthly sediment temperatures (°C) for all littoral and sublittoral locations on Lake Norman (23 February 1978 through 25 January 1979). Temperatures above 8°C (*Corbicula* biological zero) occurred from late March 1978 through mid-January 1979.

TABLE 1. Mean annual densities (no/m²), biomass (mg/m²), production (mg/m²), and turnover ratios (production/mean biomass) by zones and locations sampled in Lake Norman for *Corbicula fluminea* ≤6.0 mm in length.

ZONES AND LOCATIONS	MEAN ANNUAL DENSITIES (NO/M²)	MEAN ANNUAL BIOMASS (MG/M²)	ANNUAL PRODUCTION (MG/M²)	ANNUAL TURNOVER RATIO
LITTORAL ZONE	3040	20	516	28.4
SUBLITTORAL ZONE	891	11	182	18.4
LOCATION 2.7	6863	21	732	34.2
LOCATION 4.7	471	05	80	14.8
LOCATION 6.7	2998	17	404	23.3
LOCATION 8.7	2011	19	384	19.5
LOCATION 2.8	1092	8	117	18.2
LOCATION 4.8	552	7	81	12.0
LOCATION 6.8	1434	18	285	17.7
LOCATION 8.6	483	5	70	13.0

littoral zone. The mean annual production in the sublittoral zone was 65% less than in the littoral zone (Table 1). Production in the sublittoral zone ranged from 70 to 285 mg/m²/yr and densities ranged from 463 to 1434 m^{-2} (Table 1). The mean annual production and density in the sublittoral zone were 182 mg/m² and 891/m², respectively (Table 1). The P/B in the sublittoral zone was 16.4, with ratios ranging from 12.0 (Location 4.6) to 18.2 (Location 2.6) (Table 1). No significant differences in mean densities were detected among the four sublittoral locations ($F_{(3,152)} = 1.06$; $p>0.37$) (Table 2).

Discussion

Production estimates were made only on the clams ≤6.0 mm in length, so they probably slightly underestimate the production of the whole population, but the method is most reliable when very low densities of larger organisms are omitted (Waters 1977). High P/B ratios in both littoral (26.4) and sublittoral (16.4) zones probably result from high reproduction by *C. fluminea* ≥6.5 mm and high mortality of the clams ≤6.0 mm, as shown by the ability of only a few clams to reach the 6.5 mm size class (Fig. 2).

The increase in density of *C. fluminea* in each represented size class, except for 0.5 mm, in December 1978 and January 1979, is assumed to indicate growth of the sexually immature clams (≤6.0 mm) during the winter months. *Corbicula fluminea* 8.0 mm or larger in Lake Norman grew a maximum of 10 mm during a one-year growth study (June 1978 to June 1979) (Duke Power Co., unpubl. data). They ceased to grow when the water temperatures was between 8.8 (1 January 1979) and 6.5°C (17 January 1979) and resumed growth in March when the water temperatures reached 10-11°C. *Corbicula fluminea* reach sexual maturity during their first year at a length ranging from 6.5 to 10 mm (Aldridge and McMahon 1978; Sinclair and Isom 1963). Britton *et al.* (1979) stated that *Corbicula* in Texas could grow year-round, with water temperatures ranging from 8 to 33°C and that veligers released in the fall continued to grow during the winter reaching 10-12 mm in length by April. They also stated that larger clams showed little growth, but more field work was needed for growth during the winter season.

Lévèque (1973) used three methods (Bojsen-Jensen, instantaneous rate of individual growth and mortality, and instantaneous rate of population growth) to estimate production of *C.*

TABLE 2. Duncan's Multiple Range Test of *Corbicula fluminea* geometric mean densities (no/m²) at each location in the littoral and sublittoral zones. Densities subtended by the same line were not significantly different at the five per-cent level.

DUNCAN'S MULTIPLE RANGE TEST

SUBLITTORAL LOCATIONS	2.6	4.6	6.6	8.6
GEOMETRIC MEAN DENSITIES (NO/M2)	191	138	179	71

LITTORAL LOCATIONS	2.7	4.7	6.7	8.7
GEOMETRIC MEAN DENSITIES (NO/M2)	2890	202	892	1198

africana in Lake Chad, in Chad, Africa. The annual production estimate (1080 mg/m²) of *C. africana* (≥ 8.0 mm) was 107 and was 500% higher than the production estimates for *C. fluminea* (0.5 to ≤ 6.0 mm) in the littoral and sublittoral zones of Lake Norman, respectively. Lévêque worked with a population of *C. africana* having three cohorts. He reported that the monthly densities of clams (≥ 8.0 mm) ranged from 35 to 100/m² while the density of clams (≥ 6.5 mm) collected in Lake Norman ranged from 0 to 20/m².

Cohort P/B of *C. africana* in Lake Chad ranged from 1.7 to 2.5 and are much lower than the P/B in Lake Norman's littoral (26.4) and sublittoral (16.4) zones. *Corbicula fluminea*'s higher P/B in Lake Norman suggests that this population had greater recruitment or a greater population growth rate than *C. africana*.

The P/B of *C. fluminea* in Lake Norman can be expected to drop as the clam's population becomes better established with a higher percentage of larger clams being present in Lake Chad. As the density of larger clams increases, production of *C. fluminea* in Lake Norman can also be expected to increase.

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THE BORING CLAM, *PENITELLA CONRADI*, (BIVALVIA: PHOLADIDAE) IN NEPHRITE FROM MONTEREY COUNTY, CALIFORNIA

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ABSTRACT

Cobbles and boulders of nephrite jade collected subtidally and on Pleistocene marine terraces in Monterey County, California, contain numerous teardrop-shaped burrows typical of pholadid clams. Most burrows examined were vacant or occupied secondarily by nestling clams and other organisms. One burrow contained valves of a primary borer, Penitella conradi *Valenciennes, and represents the first record of pholadids boring nephrite. Emendation of the widespread belief that pholadids burrow only by mechanical abrasion seems justified.*

In May, 1982, one of us (Wilson) was astonished to recognize a vacant pholadid burrow in a slabbed cobble of nephrite jade (Fig. 1) offered for sale at Gorda, Monterey County, California. Inquiry disclosed that the cobble had been collected by divers off the coast nearby between Jade Cove and Willow Creek (Fig. 2). Subsequently, more than 100 burrows in cobbles and boulders of nephrite from the same area were observed by us, including some reportedly from local Pleistocene marine terraces. Such burrows are common enough to be considered a minor nuisance by the local jade dealers. Most of the burrows were empty or occupied secondarily by the nestling clams, *Hiatella arctica* (Linnaeus, 1767) or *Petricola carditoides* (Conrad, 1837), and other organisms. One burrow (Fig. 3) however, contained shells (Fig. 4) of a primary borer, the pholadid *Penitella conradi* Valenciennes, 1846, a species that ranges from Washington to Baja California Sur on the west coast of North America.

In addition to the pholadid burrows, unoccupied cup-shaped depressions with diameters as great as 80 mm occur on the surfaces of some of the nephrite boulders (Fig. 5). They are

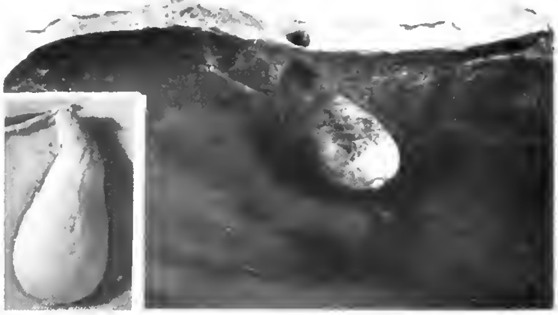


FIG. 1. Cut piece of nephrite cobble showing longitudinally sectioned pholadid burrow surrounded by dark halo. LACMIP hypotype 2480. Inset: latex cast made from this burrow. Both Figs. ×1.

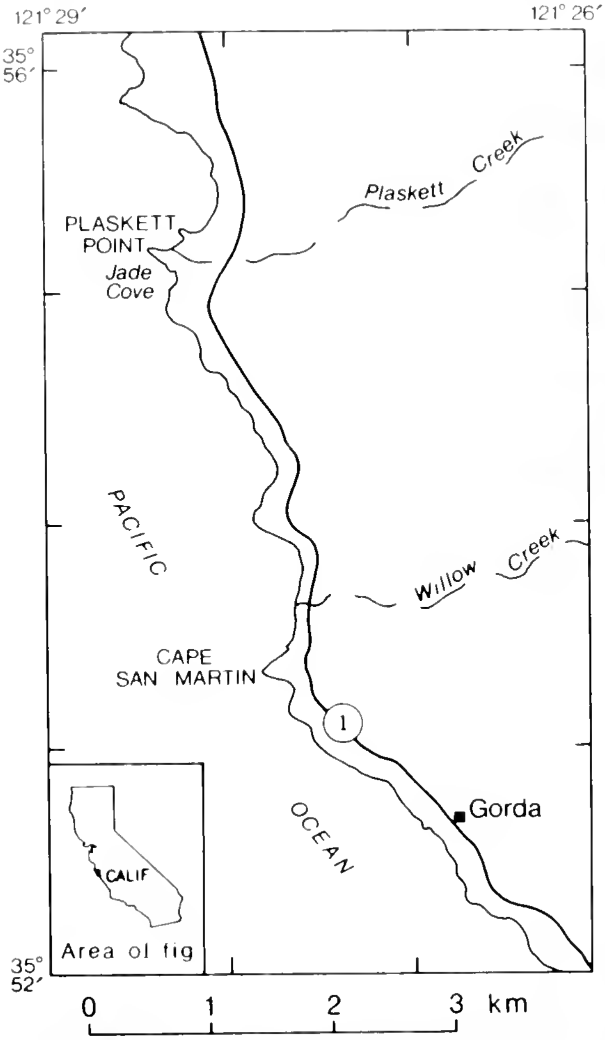
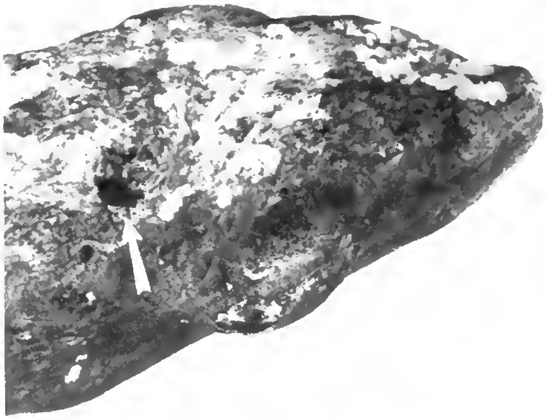


FIG. 2. Map showing general location of study area in California (inset) and more detailed map of the Plaskett Point-Cape San Martin region, Monterey County, where pholadid-bored nephrite jade occurs.



FIGS. 3-4. 3 (upper), portion of nephrite cobble with pholadid burrows. Collection of Mrs. Peggy McCain. ×0.5. 4, paired valves of *Penitella conradi* removed from burrow shown by arrow in Fig. 3. LACMIP hypotype 2481. ×2.0.

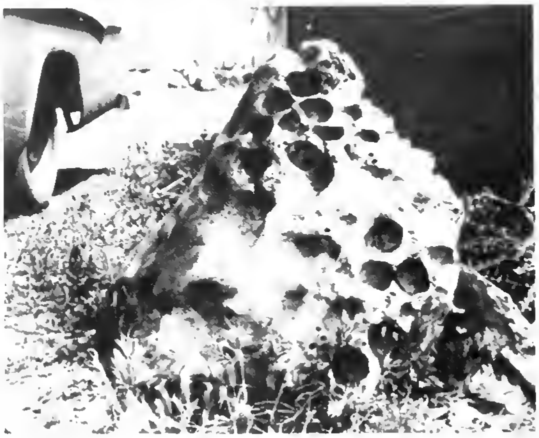


FIG. 5. Nephrite boulder showing small pholadid burrow openings and large surface depressions probably formed by echinoids. Boulder is 91 cm high. Collection of Mr. Kenneth Comello.

similar in shape and size to those formed by the sea urchin, *Strongylocentrotus* Brandt, 1835.

Nephrite

Between Plaskett Point and Cape San Martin, near Gorda, Monterey County, California (Fig. 2), nephrite crops out as lenticular masses associated with a complex of serpentine, schist, graywacke, and shale usually referred to the Franciscan Formation of Mesozoic age (Crippen, 1951). Pebbles, cobbles, and boulders derived from this formation, including nephrite, provide a substratum for epifaunal and infaunal marine organisms.

Nephrite is a silicate mineral with a legendary toughness that is due to an internal structure of filamentous crystals arranged in a dense, felt-

like pattern, making it both difficult to break and to work. All of the nephrite cobbles and boulders with burrows tested by us have a hardness of between 5 and 6 on the Mohs scale and a specific gravity of 3 to 3.44. This would seem to be an inhospitable substratum for infaunal organisms.

Burrows

All of the burrows in nephrite seen in cross-section have the typical teardrop shape of pholadid burrows (Figs. 1, 6). Selected latex casts of other burrows in the nephrite show that they have similar shapes. No burrows were seen with shapes that are typical of boring clams other than pholadids. The size of the burrows is variable, with entrances that range from 1.5 to 4.5 mm in diameter. The largest burrow has a depth of 36 mm and a maximum width of 16 mm. A darkened halo around one of the sectioned burrows is as much as 7 mm wide (Fig. 1) and strongly suggests chemical alteration of the nephrite. The hardness in the discolored zone, however, is unaltered. Halos around burrows in mudstone formed by the boring mytilid *Lithophaga* Röding, 1798, considered to be a chemical borer by most workers, were attributed to subaerial weathering by Warme and Marshall (1969).

The specimen of *Penitella conradi* (Fig. 4) was taken from a subtidally collected nephrite cobble (Fig. 3). The valves are of an adult animal with

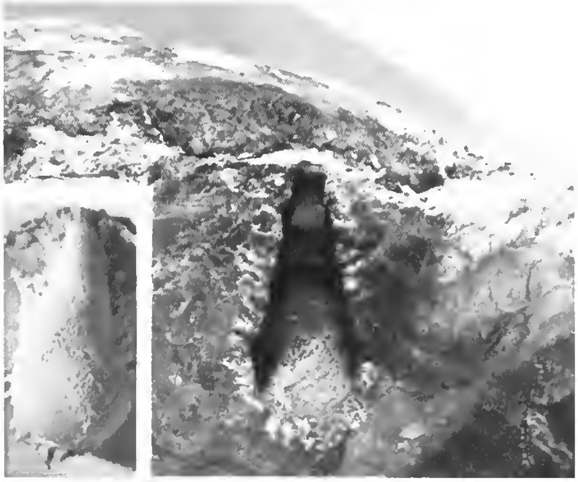


FIG. 6. Cut piece of nephrite cobble showing longitudinally sectioned pholadid burrow. Collection of Mr. Kenneth Comello. Inset: latex cast made from this burrow. LACMIP hypotype 2482. Both Figs. ×1.0.

callum and are 13 mm long (without siphonoplax). The shells are not misshapen, as is the case with some pholadids that bore into hard substrates, but the concentric ridges on the anterior slope are very tightly packed.

Discussion

"Members of the family Pholadidae bore into stiff clays or muds, shales, friable or soft rock, shells, poor grade cement, wood, nuts, or other plant products" (Turner, 1969). The implication of "soft rock" is that it is either sedimentary or relatively nonresistant to erosion. However, pholadids infrequently have been reported boring into volcanic and metamorphic rocks. Boring generally is considered to be mechanical and not chemical in nature. On the basis of wear patterns on pholadid shells, Kennedy (1974) concluded that mechanical rasping of the burrow wall was done primarily with the fore edge of the last concentric ridge of the anterior slope. The mechanics of boring in numerous species of pholadids was discussed by Röder (1977).

Reports of two researchers (Smith, 1969; Haderlie, 1976, 1979, 1980) contradict the traditional view that pholadids bore only mechanically.

The process of boring by *Penitella conradi* was studied by Smith (1969). After examination of California abalone shells bored by this species, he concluded that "the role of mechanical abrasion by *P. conradi* is minor . . . The boring process in *P. conradi* proceeds mainly by chemical dissolution of the calcareous substrate". He suspected that epithelial glands in the mantle were used for chemical dissolution of the abalone shell.

Smith (1969) also observed that during the characteristic rocking motion of the pholadid boring cycle, the mantle of *P. conradi* was in contact with the anterior burrow wall as far as the maximum diameter of the burrow and that it simultaneously covered most of the anterior portions of the valves. Apparently a biochemical secretion was being deployed to the calcareous substrate by specialized cells in the mantle. The mantle was then withdrawn and the rotation cycle initiated, during which the mechanical abrasion occurred.

Haderlie (1976, 1979, 1980) reported that *P. conradi* and six other species of pholadids bore

into siliceous sediments of the Monterey Shale in Monterey Bay, California. The rocks were reported to be chert and to have a hardness of seven on the Mohs scale.

The presence of burrows of *P. conradi* in nephrite seems to substantiate the findings of Smith (1969) that the species uses chemical assistance for boring and Haderlie (1976, 1979, 1980) that it somehow bores into substrata much harder than its shell. Further studies are necessary to elucidate the method of substratum dissolution.

Acknowledgments

We are grateful to Mrs. Peggy McCain of Beverly Hills and to Messrs. Kenneth Comello, "Jade Ron", and Robert York of Gorda for allowing us to examine specimens from their collections. Dr. A. R. Kampf, Curator of Mineralogy at the Natural History Museum of Los Angeles County, verified the identification of the nephrite. Drs. J. H. McLean, D. R. Lindberg, L. N. Marincovich, E. J. Moore, and R. D. Turner reviewed the manuscript.

The shells of *Penitella conradi* and selected specimens of nephrite with pholadid burrows are in the Natural History Museum of Los Angeles County, Invertebrate Paleontology Section (LACMIP) as hypotypes 2480-2482.

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THE MIDWESTERN NAIAD *UNIOMERUS TETRALASMUS* IN WEST VIRGINIA

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ABSTRACT

Uniomerus tetralasmus *is typically considered to be a midwestern species. Two locality records for this species within the State of West Virginia constitute a significant increase in its known range. Additional notes on habitat, age and size of individuals, and population densities are included.*

Murray and Leonard (1962), Parmalee (1967), and LaRocque (1967) all give a geographic distribution for *Uniomerus tetralasmus* that generally centers around the Mississippi River valley. LaRocque (1967) gives the easternmost localities: one from the Scioto River in central

Ohio and a second locality from the Licking River in central Kentucky. David Stansbery (pers. comm.) has a recent single specimen from the headwaters of the Muskingum River system in eastern Ohio. I have been unable to find any previous record of this species occurring in West Virginia. This paper presents data on two localities within the state.

Locality #1

Three Ohio River specimens of *U. tetralasmus* are currently housed in the Marshall University Malacological Collections. All are from the same locality (River Mile 178.1) at the upstream end of Halfway Island near Parkersburg, West Virginia. They were found as fresh dead shells and therefore cannot be sexed. Their measurements are as follows.

Specimen #	*L.*	*H.*	*W.*	*Age*
1	40 mm	23 mm	11 mm	3
2	50 mm	27 mm	n.m.	4
3	84 mm	42 mm	26 mm	5

These specimens obviously represent a stable, though small, population. These are the only specimens found even though many collecting trips to this area have been made in recent years. One specimen was collected in 1979 and the other two in May 1982. Little can be said about the habitat where they were found as they were dead and had been washed or carried ashore. They were, however, in the vicinity of the long sand and gravel bar that extends upstream from the island.

Locality #2

This locality is a far more interesting find for a variety of reasons. First, it is represented by a population of literally hundreds of living specimens; secondly, the population is located in a rather small (less than .5 acres) farm pond; and thirdly, it is anyone's guess as to how they arrived and became established there. This small pond is located about 65 km east of the Ohio River. It is, however, close to the Kanawha River, but the lower Kanawha has been essentially devoid of mussel life for many years (Taylor, 1983). The pond is located on private property near the village of Scott Depot, Putnam County, WV.

Discussion

In July of 1984, Ms. Brenda West, a graduate student at Marshall University, brought in several large mussels to be checked for parasites as part of a Parasitology lab. The shells were brought to me for identification; they proved to be *Uniomerus tetralasmus*. I sought and got information on the location of the pond and returned to the site in September. I and a student, Mr. Chris Estep, surveyed the pond using SCUBA gear to ascertain the size of the population, the pond depth, type of substrate, and the habitat preference of any of the mussels in the pond. What we found is as follows:

1. *U. tetralasmus* is the only naiad currently living in the pond.
2. It is a spring-fed pond and is quite cold even though local daily temperatures at this time of year average around 30°C.
3. The substrate consists in places of fine clean sand and pebble-size gravel. In other places there is a 30-40 cm thick layer of silt.
4. The mussels seem to have no preference as to substrate. In many instances they are buried in the sand and gravel under the silt.
5. Individuals show no preference for depth as they appear to be equally distributed throughout the pond from the deepest part (approximately 3 m) to water less than 10 cm deep.
6. They are present in large numbers.
7. They are reproducing as several size and age classes are represented in the series collected.

The Putnam County pond specimens were collected 11 September 1984. They were returned to the laboratory where the soft tissues were removed and preserved for future study. None of the 32 live-taken specimens dissected showed any evidence of being gravid with glochidia even though this is very close to the dates when Utterback (1916) reported finding gravid *U. tetralasmus* in Missouri.

These specimens are quite large. Ten specimens were arbitrarily selected to show the size

and age class range. These data are included in the following chart.

Specimen #	*L.*	*H.*	*W.*	*Approx. Age.*
1	149 mm	71 mm	48 mm	14
2	145 mm	72 mm	47 mm	15
3	148 mm	73 mm	49 mm	12
4	136 mm	66 mm	43 mm	10
5	127 mm	61 mm	39 mm	10
6	120 mm	58 mm	38 mm	9
7	111 mm	56 mm	36 mm	10
8	105 mm	53 mm	33 mm	8
9	101 mm	51 mm	32 mm	9
10	96 mm	49 mm	31 mm	8

Most of the specimens are in the 140-150 mm size class. Utterback's (1916) largest figured specimen was 80 mm long and Murray and Leonard (1962) figured a 4½ inch (= approx. 115 mm) specimen.

The current owner of the pond property, Mr. E. D. Hardman, has owned the farm for 30 years and the pond was present when he purchased the land. The age of the pond is unknown. It is man-made with an earth dam.

The occurrence of *U. tetralasmus* in West Virginia is quite a surprise for several reasons. It is well outside the previously known range. The large size of the Putnam County pond specimens and also the large number of individuals appear to indicate that living conditions are not marginal. They can live and do remarkably well under these environmental conditions.

One must now ask, how did it get there? The only reference to a host fish species was given by Sterns and Felder (1978). They used anecdotal evidence and concluded that the Golden Shiner was the host fish for *U. tetralasmus* in Louisiana. The Golden Shiner's range does not come to within a thousand miles of the State of West Virginia. Glochidia could have been brought in attached to bait minnows which had originally been seined in some southern or midwestern stream. Several naiadologists suspect that larval clams may be distributed as a result of being attached, via byssel threads, to aquatic birds' feet and then releasing in a different pond at a later time.

It would appear that in order to address the many unanswered questions about this population we must first determine what fish is serving as a larval host. Are there other populations in similar ponds in the immediate area? When is, and what is the length of, the breeding season for this species in this area? It is hoped that some light will be shed on these questions as I intend to monitor this population for years to come.

Voucher specimens have been placed with the Ohio State University Museum of Zoology and Marshall University Malacological Collections.

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NEWS

OF SEA AND SHORE, a popular magazine on shelling, has ceased publication after thirteen fruitful years of serving amateur conchologists. Tom Rice, the editor, will continue his Sheller's Directory of Clubs, Books, Periodicals and Dealers and his Catalog of Dealers' Prices for Marine Shells. He will also expand his activities at the "Of Sea and Shore Museum" in Port Gamble, Washington. Tom will join the editorial staff of the new popular magazine, "Shells and Sea Life" which is headed by Steve Long and Sally Bennett (505 East Pasadena, Phoenix, AZ 85012). If you were a subscriber to *Of Sea and Shore*, and are owed numbers, you will be sent *Shells and Sea Life* as substitutes. Tom's last number was vol. 13, no. 2. We all thank him for giving the general public such an interesting magazine on shelling and wish *Shells and Sea Life* a prosperous and long future.

–R. Tucker Abbott

CONSTRAINTS TO ADAPTIVE RADIATION IN DEPOSIT-FEEDING PELECYPODS

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ABSTRACT

Deposit-feeding pelecypods must be mobile, infaunal animals confined to a soft bottom. Because of these constraints, deposit feeders are never rock or wood borers, shell-cemented to the bottom, or, as adults, attached by a byssus. Primitive suspension-feeding pelecypods probably gave rise to deposit feeders during the early Ordovician.

Deposit-feeding is a specialized mode of obtaining food and is found in about 13,000 living species of animals. It occurs only in animals with both mouth and anus and occurs mainly in coelomates but also is found in a few pseudocoelomates. Deposit-feeding is not found in the most primitive multicellular animals (Nicol, 1981). Deposit-feeders must be mobile solitary animals. Nicol and Jones (in press) have noted that deposit-feeding animals are of small to moderate size. Whales, giant squids, and other truly large animals are not deposit feeders.

The majority of living species of pelecypods are suspension-feeders, but the protobranchs and some tellinaceans are deposit-feeders. Deposit-feeding pelecypods are restricted to a soft bottom and are all infaunal. The protobranchs are ideally suited for life in the oozes of the abyssal and hadal regions (2,000 m or greater depths) and are the dominant group in the deep sea (Knudsen, 1970). Deposit-feeding pelecypods have not invaded fresh water, but it is difficult to explain this fact. These pelecypods are of small to medium size, rarely attaining a length of more than 100 mm (Nicol, 1964). This appears to be true of fossil as well as living species. Living deposit-feeding pelecypods are rapid burrowers that have a low to moderate convexity; they do not have the inflated valves of *Glossus* or *Meiocardia*, which are slow burrowers (Nicol, 1983). Because mobility is necessary, the shells are never thick or massive, and ornamentation is either lacking or subdued. Spinose shells, as in *Arcinella*, are never present. Unlike some species of the pectinaceans and ostreaceans, they are either equivalved or only slightly inequivalved. Deposit-feeding pelecypods have retained the primitive dimyarian condition of the adductor muscles. The necessity of mobility and infaunal life also prevents deposit feeders from being shell-cemented to the bottom or byssally attached as adults. Rock boring, wood boring, and nestling are all unavailable adaptations to deposit feeders but are found in some suspension feeders. No commensal species occur in deposit-feeding pelecypods, and none has symbiotic algae in the mantle. None of them is able to swim. The mobile infaunal life of deposit feeders places many morphologic and habitat constraints on these pelecypods. For example, all of the protobranchs show less adaptive radiation than the arcaceans, which can be burrowers (infaunal), semi-infaunal, attached by a byssus (epifaunal), or, in one rare instance, rock boring.

The mud-grubbing deposit feeder is commonly thought to be a primitive animal. The first deposit-feeding pelecypods were protobranchs that appeared in the earliest Ordovician. However, the Order Actinodontoida appeared in the middle Cambrian and includes the Modiomorphidae, Cycloconchidae, Lamellodontidae, Carydiidae, and Lyrodesmatidae (N. J. Morris, 1967). These pelecypods do not resemble protobranchs and were probably suspension feeders. It is likely that early in the evolution of the pelecypods a primitive suspension-feeding stock gave rise to the deposit-feeding protobranchs at about the beginning of the Ordovician.

It is often difficult to interpret the type of

feeding a group of extinct invertebrates had, but I cannot see that any of the rostroconchs were deposit feeders. Their thick shell and convex form must have made their mobility as adults difficult; they were most likely all suspension feeders (Nicol, 1982). In a recent article on the Hyolithida and its relatives, Yockelson (1984) thinks that these extinct molluscs were detritus (deposit) feeders. However, he admits that the elongate conical shell would make it difficult for these animals to move about. For this very reason, I would think that deposit feeding would be an unlikely mode of feeding in these animals. From observations on living detritus or deposit-feeding animals, it appears that they are not primitive but specialized animals. In multicellular animals, deposit-feeding probably arose after herbivores and suspension-feeders, and possibly after scavengers and carnivores as well.

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OBITUARY

We regret to announce the sudden death of Dr. Zinaida A. Filatova, a well-known and well-liked Russian malacologists, on June 11, 1984, in Moscow, USSR, at the age of 78. She was born October 8, 1905, in Simferopol, USSR. She succeeded her professor, L. H. Zenkevich, as head of the Benthic Laboratory at the Shirshov Institute of Oceanology in 1972 and retired in 1979. She published over 120 papers on deepsea mollusks, her last issued in 1984 on "New Data on the Abyssal Monoplacophora from the Pacific and South Atlantic Oceans" (with Moskalev and Starobogatov). She was internationally renowned for her personal kindness and excellent scientific contributions. A more complete account was published in "Shells and Sea Life", (Phoenix, Arizona), vol. 16, no. 8, p. 118.

–R. T. Abbott

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